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ECONOMIC MODELS FOR PROJECTING INDUSTRIAL CAPACITY FOR DEFENSE PRODUCTION: A REVIEW

R. William Thomas

February 1983

Prepared for

Office of the Under Secretary of Defense for Research and Engineering

INSTITUTE FOR DEFENSE ANALYSES
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This paper compares three models which have been developed to analyze the economic impact of defense expenditures: the Defense Economic Impact Modeling System (DEIMS), the Revised Growth for Industrial Potential (REGRIP) model, and the Industrial Mobilization Potential Model (IMPMOD). All three models use the same basic projection methodology, input-output analysis. However, they

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differ in many important respects, including the details of their methodology, level of detail, data sources and types of reports generated.

The paper (1) discusses each model in detail, (2) provides summary comparisons of their characteristics, and (3) makes recommendations on the appropriate model for DoD to use for different types of economic analyses of mobilization.

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Contract MDA 903 79 C 0202
Task T-203

PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Office of the Deputy Under Secretary of Defense for Acquisition Management (OUSDR&E/AM) under Contract No. MDA903 79 C 0202, Task Order T-203, dated November 1982.

The purpose of the research was to compare the three models which have been developed to analyze the economic impact of defense expenditures: the Defense Economic Impact Modeling System (DEIMS), the Revised Growth for Industrial Potential (REGRIP) model, and the Industrial Mobilization Potential Model (IMPMOD). All three models use the same basic projection methodology, input-output analysis; however, they differ in many important respects, including the details of their methodology, level of detail, data sources and types of reports generated. The paper discusses each model in detail, provides summary comparisons of their characteristics, and makes recommendations on the appropriate model for DoD to use for different types of economic analyses of mobilization.

This paper, dated February 1983, is issued in fulfillment of the contract.

FOREWORD

This paper compares three models which have been developed to analyze the economic impact of defense expenditures: the Defense Economic Impact Modeling System (DEIMS), the Revised Growth for Industrial Potential (REGRIP) model, and the Industrial Mobilization Planning model (IMPMOD). Although all three models use the same basic methodology--input-output analysis--they differ in certain important respects, including their theoretical methodology, level of industry detail, data sources, and types of reports generated.

This comparison is made to acquaint potential users with the capabilities of each model and how they differ. It does not reach conclusions on which model is "the best." Indeed, the best model for any particular application will depend on the questions being addressed. The final section of the paper considers various problems and appraises the usefulness of each model for each application.

ACKNOWLEDGMENTS

The idea for this paper originated with John E. DuBreuil, Staff Director, Industrial Resources, OUSDR&E(AM). His support for the effort and his willingness to educate me to the fine points of DoD industrial planning are greatly appreciated.

The author benefitted from extended discussions with Dr. David Blond, Office of the Secretary of Defense, who developed the DEIMS model; with Mr. E. Lawrence Salkin of the Federal Emergency Management Agency, the developer of GRIP and REGRIP, and with Dr. Paul McCoy, who created IMPMOD. All of the above were kind enough to review the descriptions of their models in this manuscript.

In addition, the paper was much improved by the critiques of Mr. Roderick Vawter, Mobilization Concepts Development Center, National Defense University, and Lt. Col. Thomas K. Moore, Logistics Directorate, Joint Staff, who were able to appraise the discussion from a model-user's viewpoint. I owe them all my thanks for their careful scrutiny of this paper. Needless to say, responsibility for any remaining errors rests with the author.

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EXECUTIVE SUMMARY

This study consists of a review and comparison of three economic models which have been developed to analyze the economic impact of defense expenditures. The three models are:

- The Defense Economic Impact Modeling System (DEIMS)--developed and maintained by Program Analysis and Evaluation, OSD,
- The Revised Growth for Industrial Potential (REGRIP) model--developed and maintained by the Federal Emergency Management Agency, and
- The Industrial Mobilization Planning Model (IMPMOD)--developed and maintained by the Institute for Defense Analyses for the Office of the Deputy Under Secretary of Defense for Acquisition Management.

The research reported here was performed under Task Order No. T-203 from the Defense Advanced Research Project Agency. The Task Order specifies:

"3. OBJECTIVE:

The objective of this study is to improve the capability of the Director for Industrial Resources (OUSDRE) to identify those industries and commodities whose capacity most critically constrains the ability of U.S. industry to meet the requirements associated with peacetime [defense production] and mobilization. This study will analyze existing models used to project industrial requirements and capacity and make recommendations concerning application and overall improvement to these systems."

More specifically, the scope of the study is defined (in part) as follows:

"(a) This study will identify the strengths and limitations of each methodology application and make recommendations to the Director of Industrial

Resources [OUSDRE(AM)] as to which capabilities should be incorporated into studies performed by or for Acquisition Management.

(b) This study will address those capabilities which these or other studies lack, whose development should be supported by Acquisition Management to improve its industrial analysis capability.

(c) This study will explore the possibility of combining the best features of the various models into one system, and will identify the model which should serve as the base for such a facility."

A. ACQUISITION MANAGEMENT'S INFORMATION NEEDS

Ideally, Acquisition Management would have a comprehensive information system to (a) provide information on the current capabilities of the defense industrial base and the current demands being placed on it as well as (b) make forecasts of future industrial capacity and estimate the impact of various procurement scenarios, including mobilization, on that capacity. At the present time, both the data available and the systems to access that data fall short of this ideal.

Table S-1 illustrates some of the analytic and data resources currently available to Acquisition Management. The columns of the table progress from economy-wide analyses to detailed studies of individual firms and products. At the economy-wide level, aggregate measures of the present or future impact of defense spending on the economy are available through the widely used U.S. GNP forecasting models. At the other end of the spectrum, data on production capacity of selected defense contractors are available through the Industrial Preparedness Planning (IPP) process.[1]

[1]However, the quality of this information varies from Service to Service and among the individual Commands responsible for IPP data collection. DARCOM currently leads in developing systems to collate and analyze IPP data.

Table S-1. ANALYTIC AND DATA RESOURCES

	Economy-Wide Studies	Industry-Specific Studies	Defense Sector Studies	Firm and Product-Specific Studies
Sources of Data	National Income and Product Accounts, Flow of Funds, Budget	U.S. Inter-Industry Transactions Tables (1972), Survey of Plant Capacity	[Not Readily Available Currently]	Provided by Defense Contractors and Other IPP Participants
Method of Processing Data	U.S. Macroeconomic Models (DRI, Chase, Wharton, OMB, etc.)	U.S. Inter-Industry Models (DEIMS, REGRIP, IMPMOD)	[None Available Currently]	IPP Planning Activities of the Services
Forecast Products	GNP; Defense Spending; Inflation	Output and Capacity at the Two- Through Four-Digit Standard Industrial Classification Level	Output and Capacity at the Five- Through Six-Digit SIC Level for Defense Industries	Current Capacity, Actual Production and Reserve Capacity for IPP Participants and Defense Contractors

As noted in Table S-1, there are no comprehensive data collected at the product-group or product level (the level of industrial detail most relevant to Acquisition Management's concerns). The best available data on industrial production and capacity are aggregated to the Standard Industrial Classification (SIC) four-digit industry. Examples of defense-related four-digit industries are:

- Complete guided missiles (SIC 3761)
- Tanks and tank components (SIC 3795)
- Non-ferrous forgings (SIC 3363)
- Communications equipment (SIC 3662)
- Shipbuilding and repairing (SIC 3731).

While more detailed data would be highly prized, the available data do allow assessment of the overall level of production activity in some significant defense-related industries. For forecasting applications beyond the current capabilities, a methodology is required to assess the industrial requirements of future defense budgets and combine them with estimates of civilian demand for these industries. The models which have been developed for this task are the focus of this report.

B. INPUT-OUTPUT MODELS OF THE ECONOMY

All the models considered share certain methodological features. They use the same method and data to translate DoD budget outlay estimates into levels of production for each industry. As an example, out of every dollar of U.S. Navy procurement outlays for aircraft, (roughly) 35 cents is actually paid to the aircraft industry, 22 cents to the communications industry (for the avionics systems), 9 cents to the aircraft engine industry, and the remaining 34 cents to various other industries.

The above allocation reflects only the *direct* outlay of funds by the Navy. Indirectly, many other industries share in the production of and proceeds from aircraft through their roles as subcontractors, suppliers of parts and materials, or suppliers of services to the prime contractors. The methodology of input-output analysis is used to calculate the *indirect requirements* associated with items the DoD purchases. All three models use data on inter-industry transactions to determine these indirect defense requirements. The same methodology is used to assess the level of industry output associated with civilian final demand (consumer spending, business investment, exports, state and local governments' spending, and federal civilian budgetary outlays). Thus, the total requirements placed on each and every industry may be determined and compared to industrial capacity.[1]

C. COMPARISON OF MODELS

Table S-2 briefly summarizes the characteristics of the models. All require a macroeconomic forecast to establish the level of civilian final demand; all use the DoD Bridge Table to allocate budget category outlays to industries. Civilian final demands are similarly allocated, using procedures and data developed by the Bureau of Economic Analysis (BEA). However, the REGRIP model also can be constrained to produce only "essential" civilian demands.

1. Methodological Differences

Differences emerge as one examines the methodologies used to forecast industrial requirements. Of the three models,

[1]Census Bureau estimates of capacity are subject to questions of interpretation. It is not always clear whether engineering capacity or economic capacity is being measured.

Table S-2. SUMMARY OF CHARACTERISTICS OF THE THREE MODELS

Characteristic	DEIMS	REGRIP	IMPMOD
Basis for Macroeconomic Forecast	DRI Macro Model	Chase Macro Model	DRI Macro Model
Methodology to Generate DoD Final Demands	DoD Bridge Table	Same	Same
Methodology to Generate Civilian Final Demands	BEA Bridge Table	"Essential" Demands Specified	BEA Bridge Table
Methodology to Predict Industrial Requirements	Standard Input-Output	Standard Input-Output	Dynamic Input-Output
Methodology to Forecast Capacity Expansion	None	Dynamic Linear Programming Model	Straight Line Extrapolation
Number of Industry Sectors Presented			
All Industries	400	115	236
Manufacturing Industries	318	84	183
Number of Occupational Groups Forecast	72	40	None
Number of Critical Materials Forecast	63	18	None
Forecast Horizon			
Number of Years	5[a]	4[b]	10
Simulation Period	Annual	Semiannual	Monthly[c]
Responsible Organization	Program Analysis and Evaluation (PA&E)	Federal Emergency Management Agency (FEMA)	OUSDRE(AM) Industrial Resources
Operating Agency	Program Analysis and Evaluation, with Support from DRI	Federal Emergency Management Agency	Institute for Defense Analyses
Point of Contact:	Dr. David Blond	Mr. Lawrence Salkin	Dr. R. William Thomas
Total Development Cost	$75,000[d]	$130,000	$75,000

[a] Could be extended with programming changes.

[b] Currently limited to two years by the capacity of the FEMA computer system. The system is being installed on the OJCS computer system without this limitation.

[c] Weekly or quarterly periods are a user option.

[d] Estimated by the author.

DEIMS uses the most traditional approach--the standard input-output procedure to first estimate DoD final demand and then determine the associated direct and indirect industrial requirements. REGRIP imbeds the input-output model within a linear programming framework, and then seeks to maximize the value of defense production subject to meeting civilian requirements and to capacity, labor, and materials availability.

IMPMOD uses a dynamic input-output methodology. Using data on production processing times for industry, it not only calculates the indirect requirements from the lower-tier industries, it dates these requirements relative to the manufacturing and delivery of the final product.

2. Prediction of Capacity Expansion

DEIMS makes no use of capacity data at all. IMPMOD projects increases in industrial capacity on the basis of external information, then compares the increased requirements associated with mobilization with these capacity projections.

By contrast, REGRIP has a sophisticated procedure for (a) determining which industries are constraining a mobilization because of capacity limitations and (b) programming investments to expand capacity.

3. Available Detail

DEIMS exhibits the most detailed data on output requirements, including as it does 400 industrial sectors. IMPMOD has 236 sectors, while REGRIP has 115. However, the major difference lies with the level of detail preserved for sectors which are not significant contributors to defense production.

Both DEIMS and REGRIP include labor and material forecasts, while IMPMOD does not. In REGRIP, labor and materials availability can be constraining factors on mobilization capacity.

DEIMS forecasts labor and materials requirements based on its output forecasts, but does not contain information on the supply of these factors and does not assess whether these requirements can be satisfied.

4. Forecast Horizon

Finally, DEIMS forecasts for annual periods, while REGRIP's simulation period is semiannual, and IMPMOD's monthly. Of the three models, only REGRIP is subject to computational restrictions limiting its forecast horizon.

D. CHOICE OF MODELS FOR ANALYZING VARIOUS SCENARIOS

1. Five-Year Defense Plan (FYDP) Analysis

For determining the economic impact of the current FYDP, the best choice of model is DEIMS, although IMPMOD or REGRIP could also be used. DEIMS is preferred because of its superior industrial detail and more comprehensive treatment of industry. It might be more difficult to simulate the FYDP using REGRIP, since the design of the latter is that of an optimizing model.

2. Joint Strategic Planning Document Force Analysis

Producing the JSPD Planning Force could represent a considerably larger total budgetary impact than the FYDP. Because of the greater likelihood of encountering labor capacity and material constraints, REGRIP would be the preferred model for this exercise. DEIMS or IMPMOD results could be useful for validating the REGRIP projections.

3. Mobilization Scenario

Mobilization scenarios differ from those considered above for several reasons:

- Production of civilian goods would be curtailed
- Mobilization of military personnel may adversely affect labor availability
- Critical industries would operate at a maximum feasible output basis
- Defense goods mix would switch from hardware to consumables
- The DPA Priorities and Allocation System would be used more intensively.

Of the models considered, REGRIP best meets the analytic needs of this scenario. Its structure emphasizes the features which would be highlighted in this exercise. The major current limitation of REGRIP is its short (two-year) forecasting horizon when run on the FEMA computer.

4. Lead Times and Surge Analysis

Often, it is desired to consider not only the *magnitude* but the *timing* of indirect and direct industrial requirements associated with a surge in defense procurement. Such an exercise must consider the lead times associated with lower-tier industries which produce critical parts and components.

Only IMPMOD has the ability to simulate the impact of production lead times on the delivery of end items. It is the obvious choice for this sort of exercise.

E. RECOMMENDATIONS

On the basis of our research, the following recommendations are advanced:

(1) Acquisition Management should rely on the DEIMS forecast to establish the industrial requirements anticipated on the basis of the current FYDP.

(2) Acquisition Management should annually task FEMA to prepare an industrial mobilization analysis using REGRIP.

(3) Acquisition Management should provide adequate support to maintain IMPMOD in an operational capacity.

(4) Acquisition Management should support studies designed to provide better estimates of capacity for the most important defense industries.

(5) Acquisition Management should concentrate its Research and Development funding on studies of problems associated with the next major business cycle expansion such as potential bottlenecks, inflationary impacts, and long lead-time industries.

(6) The Bureau of the Census should be asked to orient their Survey of Plant Capacity more toward determining the physical limit of plant production.

(7) Acquisition Management should support studies to better identify the material and labor requirements of major defense weapon systems.

(8) The Joint Staff should perform an economic analysis of the attainability of the JSPD Planning Force as part of its annual planning cycle.

It is suggested that each of the three economic models discussed in this report has unique strengths for certain analyses (as well as weaknesses in other applications) and that no single model can replace their collective capabilities.

Chapter I

DOD INDUSTRIAL PLANNING FOR SURGE OR MOBILIZATION

In the event of war, or a state of crisis which increases the probability of war, DoD requirements from industry would increase significantly. For many years, the Department of Defense has developed plans for the orderly transition from normal peacetime procurement operations to full war-time mobilization of American industry. This process--termed industrial preparedness planning (IPP)--takes various forms, depending on the service, the acquisition agent, and the commodity in question, but usually involves several of the following measures:

- Maintenance of government-owned production facilities in an inoperative state or in a state of reduced manning as reserve production capacity (chiefly, ammunition plants).
- Maintenance of government-owned plant equipment packages (PEPs) to stockpile critical equipment needed to expand a producer's capacity quickly.
- Planning with prime contractors and their subcontractors for increased production in an emergency.
- Programming industrial preparedness measures (IPMs) to eliminate bottlenecks and expand production capacity.

A. OSD GUIDANCE AND MANAGEMENT OF IPP

The Under Secretary of Defense for Research and Engineering, as the DoD Acquisition Executive, has primary responsibility for the DoD IPP program. These activities center on the

Office of the Deputy Under Secretary of Defense for Acquisition Management. This office is responsible for:

- Preparing the annual Guidance on IPP,
- Preparing and revising DoD Directives and Instructions concerning IPP,
- Monitoring the Services' IPP activities and approving IPM requests.

In particular, officials in Acquisition Management must be concerned with managing IPP in the large. That is, they must be alert to external events and internal policies which impact on the IPP program, including:

- Failure of the Services to program and budget adequately to support their share of IPP activities,
- Diminished capacity of the lower tiers of the industrial base to supply materials, equipment, and products to prime contractors,
- Disincentives to government contracting, including (a) contract regulations, (b) excessive paperwork, (c) financial disincentives relative to private contracts, and (d) socioeconomic regulations.

Finally, Acquisition Management must assess the overall capacity of the U.S. economy to meet surge or mobilization requirements. It is this requirement that is the specific focus of this study.

B. INFORMATION REQUIREMENTS

Ideally, Acquisition Management would like to have available a comprehensive information system which would (a) provide information on the current capabilities of the defense industrial base and the current demands being placed on it, as well as (b) make forecasts of future industrial capability and estimate the impact of surge or mobilization on that capacity. Such a system would be capable of both gross assessments of total economic impact of the defense program and firm-specific

studies associated with individual weapon systems. At the present time, available data and systems fall short of this ideal.

Table 1 illustrates some of the current information resources available to Acquisition Management and depicts the gaps. At the highest level of aggregation, a number of macroeconomic models are available to forecast the overall economic impact of changes in the Defense budget. These models' forecast error under normal peacetime conditions runs to one percent for GNP, and two to five percent for inflation, GNP components, and employment. However, these models provide no detail on the impact of defense spending on individual industries.

This latter information is generated by inter-industry models. These models accept as inputs estimates of overall defense and civilian final demands and from these generate a detailed statement of final demand by producing industry. Using data on inter-industry transactions, the direct and indirect requirements associated with the production of these final demands can be estimated, and total production by industry determined. Additionally, using these models, it is possible to calculate the share of each industry's production devoted to defense.

Another source of information on the industrial base is DoD administrative records. These include data derived from (a) administration of DoD contracts and (b) the industrial preparedness planning process. The former source includes data on all prime contracts over $10,000 and selected information on subcontractors for prime contracts over $500,000. For each contract, these data relate such items as (a) contractor's name and location, (b) procuring agent, (c) dollar amount, (d) contract date(s), (e) procurement program and/or RDT&E category, and (f) Federal Supply Classification (FSC)

Table 1. ANALYTIC AND DATA RESOURCES

	Economy-Wide Studies	Industry-Specific Studies	Defense Sector Studies	Firm and Product-Specific Studies
Sources of Data	National Income and Product Accounts, Flow of Funds, Budget	U.S. Inter-Industry Transactions Tables (1972), Survey of Plant Capacity	[Not Readily Available Currently]	Provided by Defense Contractors and Other IPP Participants
Method of Processing Data	U.S. Macroeconomic Models (DRI, Chase, Wharton, OMB, etc.)	U.S. Inter-Industry Models (DEIMS, REGRIP, IMPMOD)	[None Available Currently]	IPP Planning Activities of the Services
Forecast Products	GNP; Defense Spending; Inflation	Output and Capacity at the Two- Through Four-Digit Standard Industrial Classification Level	Output and Capacity at the Five- *Through Six-Digit* SIC Level for Defense Industries	Current Capacity, Actual Production and Reserve *Capacity for IPP* Participants and Defense Contractors

or Service Code (SVC). Reports containing these data are regularly prepared and distributed to OSD, the Services, Congress, and the public. Recently, Data Resources Incorporated, in collaboration with Defense Marketing Services, made these data available on-line.

This represents a significant gain in information access, since users may structure their information, query and access only the relevant items in the base. For example, reports may be produced listing all contracts awarded to firms in the Boston area, or all contracts related to a particular weapon system.

The most significant gap revealed in Table 1 is the total absence of data on defense production at the product or product-group level (i.e., corresponding to five- or six-digit Standard Industrial Classification codes). While such data are rarely published or made commonly available, they are available in the form of the basic inputs to the Economic Censuses (Manufacturers, Business, Mineral Industries, etc.). Special tabulations to identify meaningful groupings of establishments producing or supporting the production of defense goods would be required.

An alternative procedure would seek to identify the defense subsectors associated with four-digit SIC industries. In either case, recourse to special tabulations of unpublished data would be necessary.

C. IMPROVING THE USEFULNESS OF EXISTING MODELS

While better data on the defense industrial base is a worthy long-term objective, a more immediate goal is to improve the usefulness of existing analytic resources. This report examines three input-output models which could be used to perform economic studies of mobilization. Chapter II describes the models and how they work. Chapter III presents a comparative evaluation of the models' major characteristics.

Chapter IV discusses the suitability of each model for particular applications. The final chapter makes recommendations regarding Acquisition Management's utilization of and support for these analytic efforts.

Chapter II

INTER-INDUSTRY TRANSACTIONS MODELS

The use of an inter-industry transactions (input-output) model to compute the direct and indirect requirements associated with the production of defense goods and services is a common feature of all comprehensive industrial mobilization analyses. This chapter discusses the input-output methodology in general and the specific way it is used in each model. The first section describes features common to all models. Succeeding sections focus in turn on unique characteristics of each model.

A. INPUT-OUTPUT ANALYSIS: THE PROCESS

1. General Description

The development of input-output analysis is generally credited to Wassily Leontiev.[1] The input-output model is a linear system which relates the activities of each industry in terms of a vector of purchases from other industries. Typically, the value of the system derives from the detail in which these industries are portrayed (the current data permit 496 industries to be included). Highly aggregated input-output models are considered to have only pedagogical value. The detailed data are required in practical applications.

The methodology distinguishes between final goods or *final demands* (which consist of personal consumption, expenditures, business investment outlays, government purchases, and

[1] Wassily Leontiev, *The Structure of the American Economy 1919-1939*, 2nd Edition, Oxford University Press, New York, 1951.

exports)[1] and *intermediate goods and services* which are sold by one firm to another for further processing or incorporation into a finished product. Every finished product (final demand) generates a set of *direct requirements* from other industries; production of the latter, in turn, generates additional *indirect requirements*. The input-output model calculates these direct and indirect requirements, through succeeding tiers of production, all the way back to the basic raw material inputs. In this manner, the total industrial requirements associated with any given set of final demands (the "bill of goods") can be determined quantitatively.[2]

2. Data Sources

The Bureau of Economic Analysis developes the estimates of the inter-industry transactions table at five year intervals as part of the National Accounts of the United States. The five year interval results from the fact that comprehensive Economic Censuses,[3] which provide the basic raw data from which the table is built, are conducted only for years ending in "2" or "7." Construction of the table is a lengthy process. The 1972 table was not published by BEA until 1979.[4] The next table, containing data for 1977, will not be available until (at least) 1984. Interim 1977 "update" tables have been constructed both by BEA and private organizations (DRI,

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[1]Imports require special consideration. Competitive imports (i.e., goods produced domestically, such as crude oil) are added to domestic purchases in the table and subtracted from final demand. Non-competitive imports (such as natural rubber) are treated as a separate input category, like labor or raw materials.

[2]A mathematical description of the input-output model appears in Appendix A.

[3]These include the Census of Agriculture, Census of Manufacturers, Census of Wholesale and Retail Trade, Census of Construction Industries, Census of Services, Census of Transportation, etc.

[4]Philip M. Ritz, "The Input-Output Structure of the U.S. Economy, 1972," *Survey of Current Business*, Vol. 59, No. 2 (February 1979), pp. 34-72.

University of Maryland, and others). However, these are synthetic products produced by other methods and should not be confused with the basic input-output table.[1]

3. Macroeconomic Assumptions and the Prediction of Final Demand

All input-output models require as a starting point a prediction of final demand by industry for the entire forecast period. The two elements required to specify these predicted values of final demand are (1) a macroeconomic forecast of GNP and its components and (2) a methodology to transform these forecast values of consumption, investment, exports, etc. into predicted final demands by input-output industry. The latter procedure makes use of a "bridge table," so-named because it bridges the gap between the more aggregated macroeconomic forecasts of final demand and the detailed industry-by-industry demand forecasts required as inputs to the input-output forecasting process.

a. Macroeconomic Assumptions

Essentially, each model has the facility to accept any set of macroeconomic assumptions; thus, this should not be a criterion for differentiating among the models. However, in practice, the developer(s) of each model select specific macroeconomic models and program the linkage between the input-output and macro model. For this reason, it is not necessarily easy or convenient to switch to a different macro model; it is much easier to change assumptions and generate a new macroeconomic scenario, using the same model.

The DEIMS system is linked to the Data Resources Incorporated quarterly U.S. Macro Model. REGRIP uses the forecast

[1]The implications of using these updated tables are discussed below in the individual model sections.

of Chase Econometrics. The IMPMOD macroeconomic forecast is the least sophisticated--a straight-forward projection that civilian demand grows by three percent per annum for every industry.[1]

b. Bridge Tables

For every model, two bridge tables are required: one for civilian final demand and one for DoD final demand. The civilian final demand bridge table was developed by the Bureau of Economic Analyses in the course of its work on the 1972 input-output table. This table performs two important tasks: (1) it distributes aggregated final demand estimates to the 496-industry level of the input-output table, and (2) it converts the pricing of final demand from purchasers' prices to producers' prices by reallocating the effects of sale taxes, wholesale and retail margins, and transportation costs from the purchased good to the using activity.[2]

The DoD bridge table is organized quite differently. It transforms estimated outlays for 55 DoD budget categories (in constant 1972 dollars) into the input-output categories. Documentation on the procedure used to construct the DoD bridge is not available, but it too presumably includes the conceptual adjustments described above to convert outlays from a purchasers' to a producers' price basis. All three models discussed in this report use the same DoD bridge table as provided by Program Analysis and Evaluation staff. An illustration of the allocation process is shown in Table 2 for Naval Aircraft Procurement.

[1]The model is currently being revised to accept forecasts from the DRI Macroeconomic Model.

[2]The need for these adjustments is further explained in Appendix A.

Table 2. ALLOCATION OF NAVAL AIRCRAFT PROCUREMENT OUTLAYS BY INDUSTRY SUPPLIERS

Industry	Share Final Demand (Percent)
Other Ordnance and Accessories	1.97
Electronic Computing Equipment	4.90
Radio and Television Communication Equipment	21.70
Aircraft	34.90
Aircraft Engines and Engine Parts	8.70
Aircraft Parts and Equipment, etc.	6.77
Measuring and Control Equipment	9.75
Wholesale Trade	1.78
All other	9.53

Source: Blond, David L., "The Defense Economic Impact Modeling System," Program Analysis and Evaluation Directorate, Department of Defense, Washington, D.C.

4. Computation of Direct and Indirect Requirements

Once the final demands by industry have been estimated for each forecast year, computation of direct and indirect requirements is a straightforward mathematical exercise (see Appendix A). Direct requirements for the defense sector are determined by matrix multiplying the input-output activity matrix ("A") by the defense final demand vector; similarly, direct requirements for the entire economy can be computed as the matrix product of the activity matrix and the vector sum of defense and civilian final demands. Indirect requirements can then be established by summing the results of successive application of the activity vector to each round of production, or (using a mathematical shortcut) multiplying the total requirements matrix ("B") by the defense and total final demand vectors, respectively.

5. Final Remarks on Methodology

This completes our discussion of the general methodology of input-output. We now address the features of each model which distinguish one from the other.

B. DEIMS--THE DEFENSE ECONOMIC IMPACT MODELING SYSTEM[1]

DEIMS has been developed for three purposes:

- "To analyze the economic impact of defense expenditures on the United States economy...
- To provide planning information on defense requirements to private sector firms...to encourage companies to add additional capacity where needed.
- To analyze the impact of alternative defense budgets on key industrial sectors, skilled labor categories, and raw material requirements."[2]

Of all the models considered here, DEIMS is the most comprehensive. Not only does it offer more detail, but also it augments its forecasts of industrial production with forecasts of labor and material requirements. DEIMS is a well-supported and maintained system which offers considerable analytic capability.

Figure 1 displays the essential elements of the DEIMS system. The starting point is the budgetary statement (in terms of outlays) of the Five Year Defense Plan (FYDP). The current standard DRI macroforecast assumptions are altered to reflect the spending totals of the FYDP, and a new forecast for the economy for the five year period is generated. Total final demand by industry is then estimated by applying the conventional DRI bridge table to the aggregated final demand

[1]This section is based on David L. Blond, "The Defense Economic Impact Modeling System," Program Analysis and Evaluation Directorate, Department of Defense, Washington, D.C.

[2]Blond, *Idem.*, p. 1.

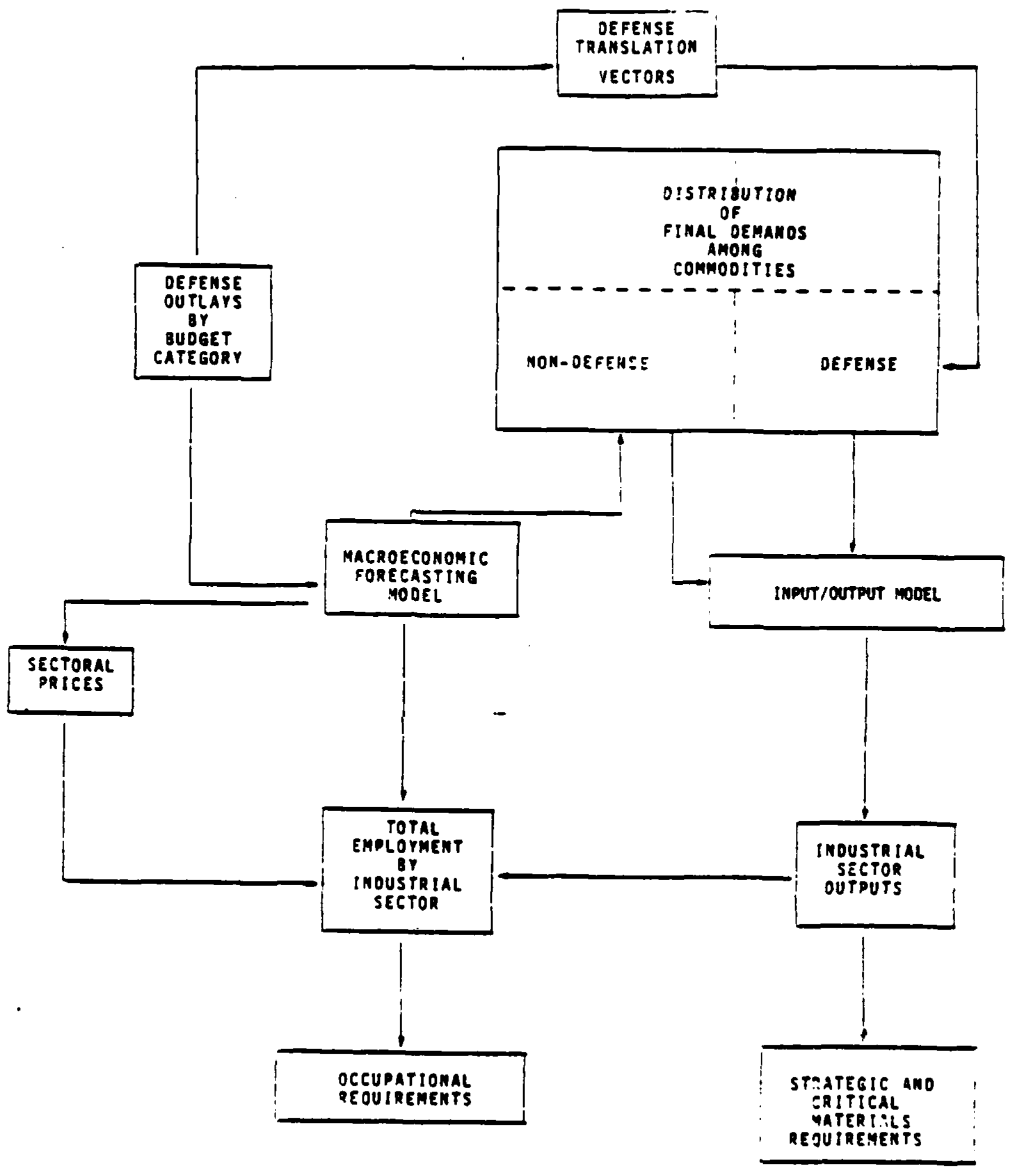

Figure 1. DEFENSE ECONOMIC IMPACT MODELING SYSTEM

components predicted by the DRI Macro Model. The sectoral output estimates are then generated by the standard input/output method.

The FYDP also serves as the starting point for estimating defense demands. However, the defense bridge table translates these directly into final demand by industrial sector. Thus, the macro model step is omitted. The input/output model is then used to determine industrial requirements associated (directly or indirectly) with defense production. These outputs are shown in Table 3.

Table 3. AN EXAMPLE OF A DEIMS INDUSTRIAL PRODUCTION REPORT

11/30/81

305. INDUSTRIAL CONTROLS

DEFENSE ECONOMIC IMPACT MODELING SYSTEM
FORECAST OF THE IMPACTS OF DEFENSE EXPENDITURES ON INDUSTRY OUTPUT
(MILLIONS OF 1980 DOLLARS EXCEPT AS NOTED)

	1981	1982	1983	1984	1985	1986	1987	AVG. ANN % GROWTH 81 TO 87
FINAL DEMAND	762	825	896	943	1,008	1,071	1,138	6.92
PERSONAL CONSUMPTION	0	0	0	0	0	0	0	--
INVESTMENT	458	527	577	593	636	679	729	8.06
EXPORTS	288	286	304	332	350	367	385	4.92
MILITARY EXPORTS	0	0	0	0	0	0	0	--
IMPORTS (-)	32	36	38	40	43	48	52	8.07
IMPORTS FOR DEFENSE	2	2	2	2	3	3	4	14.41
GOVERNMENT PURCHASES	48	47	53	59	65	73	76	7.97
DEFENSE	24	25	33	40	46	53	57	15.74
NONDEFENSE FEDERAL	20	18	15	14	14	14	14	-5.27
STATE & LOCAL	5	5	5	5	5	5	5	1.31
DOMESTIC PRODUCTION	3,358	3,609	3,881	4,090	4,335	4,587	4,818	6.20
PROD. FOR DEFENSE	154	176	206	234	263	296	314	12.56
PROD. FOR MILITARY EXP.	3	3	3	4	4	4	4	5.59
ALL OTHER	3,201	3,430	3,672	3,852	4,068	4,287	4,500	5.84
DEFENSE SHARE OF DOM. PROD.(%)	4.59	4.88	5.31	5.72	6.07	6.46	6.51	5.99
DEFENSE TOTAL REQUIREMENTS	156	178	208	236	266	299	317	12.58
IMPORT SHARE(%)	1.04	1.06	1.04	1.06	1.07	1.11	1.15	1.63
EMPLOYMENT (THOUS.)	55	58	60	63	65	68	70	4.07
EMPLOYMENT FOR DEFENSE	3	3	3	4	4	4	5	10.30
ALL OTHER	53	55	57	59	61	63	66	3.72

Once industrial output is determined, both for defense and for the entire economy, the next step is to project employment. This procedure uses the occupation by industry table developed by the Bureau of Labor Statistics. Elements of this table estimate the employment for each of 72 skilled labor categories per dollar of industry production. The process also involves an econometric employment model, developed by DRI, to predict total employment by each industrial sector. This figure is then distributed by occupation according to the BLS-estimated data. Table 4 illustrates this output.

Table 4. AN EXAMPLE OF A DEIMS EMPLOYMENT REPORT

12/23/81

DEFENSE ECONOMIC IMPACT MODELING SYSTEM
OCCUPATION BY INDUSTRY MODEL
ESTIMATES OF INDUSTRIAL EMPLOYMENT BY OCCUPATION
1. AERO-ASTRONAUTIC ENGINEERS
(THOUSANDS OF PERSONS)

INDUSTRY	81	82	83	84	85	86	87	AVG. ANN. %GROWTH 81 TO 87
DEFENSE INDUCED EMPLOYMENT								
8. ORDNANCE & ACCESSORIES	3.66	3.79	4.19	4.46	4.74	5.09	5.31	6.39
35. ELECTRICAL MACH. & EQUIP.	0.11	0.11	0.12	0.13	0.13	0.14	0.13	3.02
37. AIRCRAFT INCL. PARTS & EQUIP.	16.48	18.84	21.33	23.36	25.96	29.30	31.12	11.18
47. AIR CARRIERS & RELATED SERV.	0.04	0.04	0.05	0.05	0.05	0.06	0.06	9.58
61. BUSINESS SERVICES NEC	0.04	0.04	0.05	0.05	0.05	0.06	0.06	10.07
63. MISC. PROFESSIONAL SERVICES	0.05	0.05	0.06	0.06	0.07	0.07	0.07	6.35
73. GOVERNMENT	3.51	3.55	3.62	3.62	3.66	3.66	3.67	0.73
TOTAL, ALL INDUSTRIES	24.03	26.58	29.58	31.89	34.84	38.56	40.62	9.14
TOTAL EMPLOYMENT								
8. ORDNANCE & ACCESSORIES	4.91	4.92	5.24	5.46	5.72	6.07	6.32	4.29
35. ELECTRICAL MACH. & EQUIP.	0.74	0.70	0.70	0.68	0.67	0.67	0.66	-1.92
37. AIRCRAFT INCL. PARTS & EQUIP.	41.17	42.43	46.28	49.32	52.80	57.09	60.43	6.60
47. AIR CARRIERS & RELATED SERV.	1.04	1.03	1.09	1.13	1.18	1.24	1.29	3.68
61. BUSINESS SERVICES NEC	0.73	0.73	0.77	0.80	0.84	0.89	0.92	3.98
63. MISC. PROFESSIONAL SERVICES	1.60	1.52	1.53	1.52	1.51	1.53	1.52	-0.90
73. GOVERNMENT	13.05	12.88	12.85	12.94	13.19	13.55	13.98	1.15
TOTAL, ALL INDUSTRIES	65.10	68.02	70.33	73.74	77.86	83.06	87.16	4.98

The final output of DEIMS are forecasts for 63 strategic materials. These forecasts are built up, industry-by-industry, using historical data from the U.S. Bureau of Mines and the Department of Commerce on mineral and material requirements by each industry, relative to industry output. An example of this report is shown in Table 5.

C. REVISED GROWTH FOR INDUSTRIAL POTENTIAL (REGRIP) MODEL

The REGRIP model was developed for the Federal Emergency Management Agency (FEMA) as an analytic tool for analyses of mobilization. REGRIP combines the techniques of input-output analysis and linear programming in a dynamic optimizing model. The original FPA effort (the Growth Required for Industrial Potential (GRIP) model) was a linear programming model of industry, but did not use the input-output table.[1] REGRIP was developed in 1978 as an enhancement of the GRIP model.[2] REGRIP may be described as a dynamic input-output model, which is solved over a multi-period time interval, with capacity expansion to meet requirements as needed. The model expands capacity according to predetermined lead times and capital-output requirements and the requirements generated by the investment *are* included in the overall model estimates of industrial demands.

As formulated, the REGRIP model's objective was to maximize the weighted[3] sum of defense production by industry,

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[1]E. Lawrence Salkin, "GRIP—A Linear Programming Model to Estimate Additional Production Capacity to Satisfy Final Demand," Federal Preparedness Agency, February 1977.

[2]"A Model to Identify Potential Bottleneck Industries in a War Mobilization," Battelle Memorial Institute, Pacific Northwest Laboratories, Richland, Washington, 30 June 1978.

[3]Provision was made to assign differential weights to defense items to indicate priorities. In the solution discussed in Battelle (1978), all weights were set to one.

Table 5. AN EXAMPLE OF A DEIMS STRATEGIC MATERIAL REQUIREMENTS MODEL

11/24/81

DEFENSE ECONOMIC IMPACT MODELING SYSTEM
STRATEGIC MATERIAL REQUIREMENTS MODEL
FORECAST FOR:
9. COBALT
(THOUSANDS OF POUNDS)

INDUSTRY	1981 DOD	1981 TOTAL	1982 DOD	1982 TOTAL	1983 DOD	1983 TOTAL	1984 DOD	1984 TOTAL	1985 DOD	1985 TOTAL	1986 DOD	1986 TOTAL	1987 DOD	1987 TOTAL	AVG. AN % GROWT 81 TO 8 DOD	AVG. AN % GROWT 81 TO 8 TO
161. INORGANIC & ORGANIC CHEM	55.2	1,768.1	64.3	1,856.4	72.9	1,944.5	80.4	2,036.9	89.0	2,137.7	98.8	2,231.1	105.1	2,320.6	11.33	4
178. CHEM PREPARATIONS, NEC	12.5	356.1	14.6	375.1	16.5	393.2	18.2	412.1	20.2	433.2	22.1	453.0	23.8	474.7	11.38	4
180. PAINTS & ALLIED PROD	25.9	709.8	29.1	751.1	32.6	779.5	35.7	806.1	38.3	842.0	43.1	880.1	46.1	923.5	10.36	4
190. GLASS & PROD EX CONTAINERS	0.8	27.3	0.9	29.6	1.0	30.5	1.2	31.7	1.4	33.4	1.5	35.3	1.6	37.1	13.35	5
199. STRUCTURAL CLAY PRODUCTS	4.8	335.1	5.4	349.5	6.0	373.0	6.6	391.4	7.4	410.5	8.1	432.0	8.6	450.0	10.30	5
200. POTTERY & RELATED PROD	8.3	498.2	9.8	518.1	11.6	543.7	13.5	576.2	15.5	610.5	17.4	636.8	18.5	662.0	14.39	4
207. ABRASIVE PROD	3.8	100.3	4.4	106.4	5.1	110.7	5.7	114.3	6.3	119.2	7.1	126.0	7.6	131.9	12.10	4
230. COPPER ROLLING & DRAWING, NEC	47.6	505.0	55.9	538.4	65.4	577.6	74.0	613.2	83.0	654.2	94.7	691.8	101.6	732.1	13.47	6
231. COPPER WIRE DRAWING & INSULATING	22.6	531.9	26.7	573.3	31.2	613.5	35.4	646.6	39.6	672.4	44.3	706.2	47.1	740.7	13.00	5
234. COPPER CASTINGS, NEC	47.1	294.6	54.6	312.4	62.2	330.2	68.3	344.4	75.2	362.4	83.4	381.3	87.4	397.6	10.83	5
241. FAB STRUCTURAL METAL	0.4	11.5	0.4	11.8	0.4	12.4	0.5	12.9	0.5	13.3	0.6	13.9	0.6	14.6	10.15	4
243 FAB PLATE WORK(BOILERSHOPS)	8.9	248.6	10.3	259.5	11.4	271.1	12.7	279.3	14.4	288.1	16.2	298.0	17.1	310.9	11.56	3
250. HAND & EDGE TOOLS, NEC	1.2	53.2	1.4	55.9	1.5	58.6	1.7	61.7	1.9	65.3	2.1	68.6	2.2	71.9	10.51	5
253. PLATING & POLISHING	294.5	2,198.0	341.6	2,286.8	404.4	2,496.7	458.3	2,679.5	518.5	2,885.9	580.8	3,090.4	646.8	3,291.8	13.42	7
259. FAB METAL PROD, NEC	36.9	765.5	42.5	806.4	48.6	846.8	54.2	886.0	60.3	931.5	67.0	976.8	71.2	1,021.1	11.59	4
260. STEAM ENGINES & TURBINES	33.4	319.7	36.6	319.1	39.7	329.0	43.7	338.2	48.7	351.7	53.3	363.0	56.5	376.8	9.17	2
261. INT. COMBUSTION ENGINES, NEC	7.1	205.4	8.0	211.6	9.0	225.2	10.1	235.3	11.1	248.3	12.2	261.0	13.0	274.2	10.69	4
262. FARM MACHINERY	0.0	12.3	0.0	13.6	0.0	13.5	0.0	14.4	0.0	15.4	0.0	16.0	0.0	16.6	9.09	4
264. CONSTRUCTION MACHINERY	0.7	61.7	0.8	65.0	1.0	70.1	1.1	73.6	1.2	78.3	1.3	82.5	1.4	86.6	11.13	5
265. MINING MACHINERY, EX. OIL	0.5	71.1	0.5	73.1	0.6	77.2	0.7	81.0	0.8	85.3	0.8	89.0	0.9	94.4	11.36	4
266. OIL FIELD MACHINERY	0.2	44.0	0.3	48.5	0.3	51.4	0.3	54.5	0.3	58.1	0.3	61.6	0.4	65.6	8.66	6
268. CONVEYORS & CONVEYING EQUIP	0.8	26.6	0.9	28.3	1.0	30.7	1.0	32.0	1.2	33.7	1.3	35.2	1.4	37.1	10.11	5
270. INDUST. TRUCKS & TRACTORS	4.2	23.1	4.9	24.9	5.9	28.1	6.2	29.4	6.2	30.7	6.5	32.0	6.9	31.0	8.71	6
271. MACH TOOLS, METAL CUTTING	35.0	509.9	40.6	553.1	47.5	611.1	54.2	656.7	60.7	687.9	68.7	725.2	72.9	763.3	13.02	6
273. SPECIAL DIES, TOOLS, ACCESS.	117.3	1,774.1	135.9	1,896.9	157.6	2,060.7	177.0	2,147.3	198.5	2,242.0	223.0	2,352.0	237.1	2,486.6	12.45	5
276. METALWORKING MACH, NEC	18.1	320.6	21.3	356.5	25.9	400.8	30.4	421.9	34.9	449.4	40.6	478.5	43.1	490.6	15.53	7
322. RADIO & TV COMMUNICATION EQUIP	656.6	1,296.7	751.6	1,393.2	880.1	1,572.9	1,009.1	1,727.8	1,144.9	1,891.8	1,280.9	2,060.5	1,366.2	2,182.4	12.99	9
329. ELECTRONIC COMPONENTS, NEC	362.8	1,349.1	300.6	1,454.5	372.4	1,632.1	430.4	1,819.5	492.9	2,000.4	560.6	2,170.6	603.0	2,347.0	14.04	9
330. MOTOR VEHICLE PARTS & ACCESS.	2.4	106.0	2.8	117.0	3.3	122.2	3.9	127.1	4.3	133.1	4.7	140.3	5.0	147.2	12.69	9
336. AIRCRAFT ENGINES & ENGINE PARTS	2,073.3	4,320.4	2,448.8	4,670.5	2,837.1	5,207.4	3,133.3	5,613.3	3,547.6	6,136.2	4,012.7	6,735.1	4,255.5	7,121.9	12.73	8
TOTAL	3,782.2	18,792.2	4,420.4	20,008.4	5,160.4	21,816.6	5,767.9	23,251.9	6,506.3	24,985.5	7,369.1	26,646.0	7,820.5	28,121.2	12.89	6

subject to meeting essential civilian requirements. This often led to increases in production of goods whose industrial requirements could be easily met, far beyond any conceivable wartime requirement. This problem was addressed in a later version of the model[1] (termed Augmented REGRIP) by redefining the problem to be solved. In this version, the linear programming problem is to *minimize the cost* of producing specified requirements of defense and essential civilian goods (cf. Figure 2).

Unlike the other models considered in this study, REGRIP both identifies those industries whose capacity constrains defense expansion and forecasts the increase in capacity which is feasible over its forecast horizon.[2] The solution for the initial semi-annual period targets industries which require expansion. The delay in constructing these facilities is determined from the capacity lead-time data, and the industrial requirements associated with their construction are added to the total requirements vector of the model. If the time delay is shorter than the model's forecast horizon, the additional capacity becomes available and is utilized in later solution periods of the model.

D. INDUSTRIAL MOBILIZATION POTENTIAL MODEL (IMPMOD)

The last model considered by this paper is the Industrial Mobilization Potential Model, developed in 1981 by Dr. Paul McCoy of the Institute for Defense Analyses, under contract to OUSDRE(AM). IMPMOD is the first input-output model to explicitly incorporate *production lead-times* into its theoretic formulation.[3] It does this by establishing a processing time

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[1]D.B. Belzer and R.J. Nesse, "A Model to Identify Potential Resource Constraints in a War Mobilization," Battelle Memorial Institute, Pacific Northwest Laboratories, Richland, Washington, August 1979.

[2]This procedure is explained in detail in Chapter III.

[3]Note that REGRIP uses lead-time data for capacity expansion, but not for production relationships.

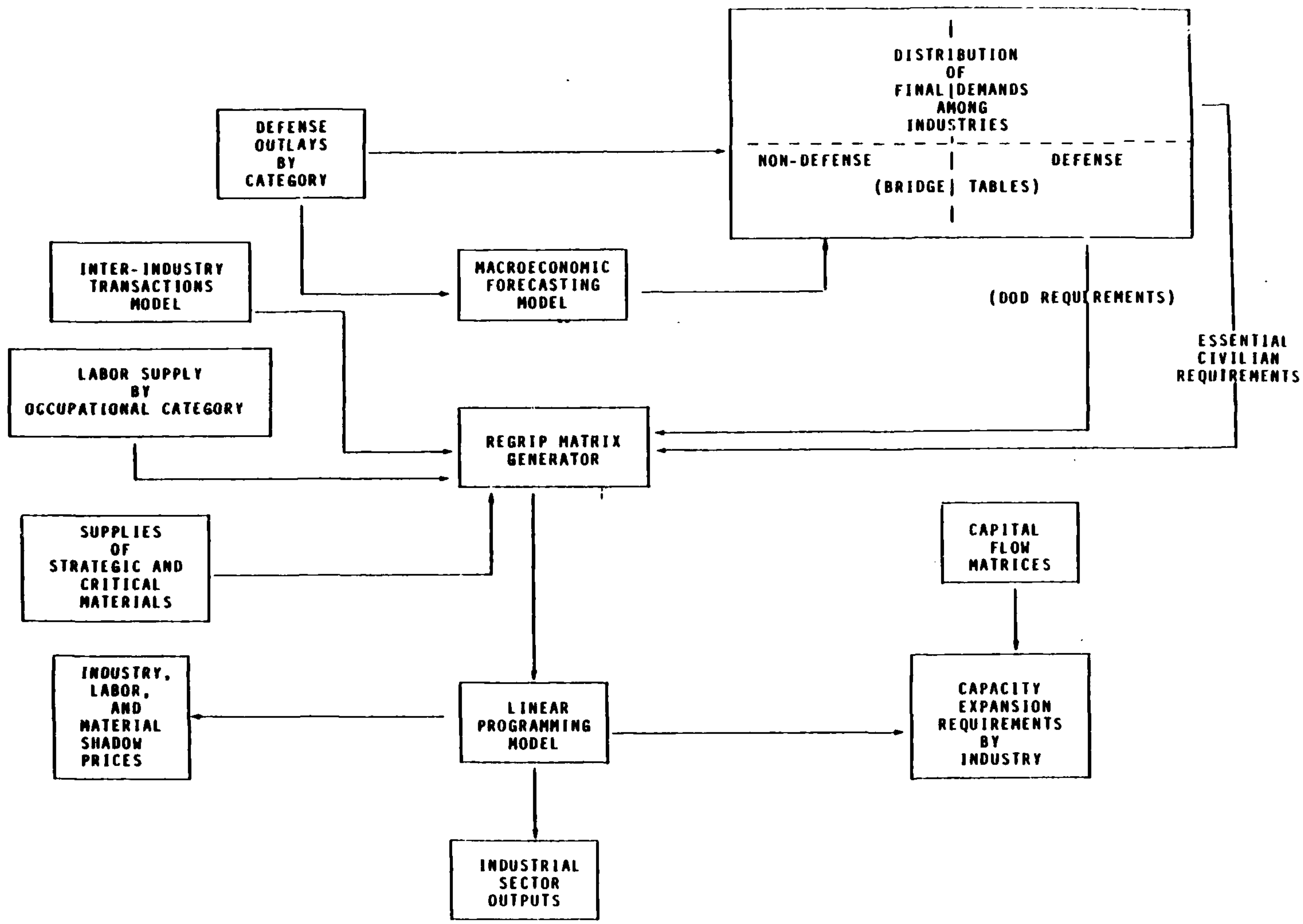

Figure 2. REVISED GROWTH FOR INDUSTRIAL POTENTIAL MODEL (REGRIP-MIN)

for every input-output industry. Because of this modification, standard methods for solving the input-output model are inapplicable. Instead, IMPMOD works backwards in time as it computes the direct and indirect production requirements. That is, a target vector of final demand requirements is established for some future period (e.g., 1987). The model then calculates the time required for manufacturing these products and the direct requirements of materials and supplies from other industries necessary to the production of the final demand quantities.

These direct requirements now constitute another source of *indirect* requirements, distributed over time through the period prior to 1987 according to the processing time of each industry. From these the distribution over industry and time of the total (direct and indirect) industrial requirements associated with a given vector of final demands may be calculated by successive application of the input-output table in the standard manner (cf. Figure 3).

Over the entire forecast period the sum of all industrial requirements associated with producing the 1987 final demand vector will equal that predicted by any standard input-output model. The difference is that the standard model would predict that these industrial requirements would all occur in 1987, while IMPMOD would distribute them over the entire period 1982-1987.

IMPMOD's industrial requirement predictions are not constrained by existing capacity. Rather, the predicted values for industrial production are compared with projections of capacity in order to identify those industries which will act as bottlenecks on a planned expansion in defense production. In current simulations performed using IMPMOD, these capacity projections were simple extrapolations of growth from known capacity in 1978.

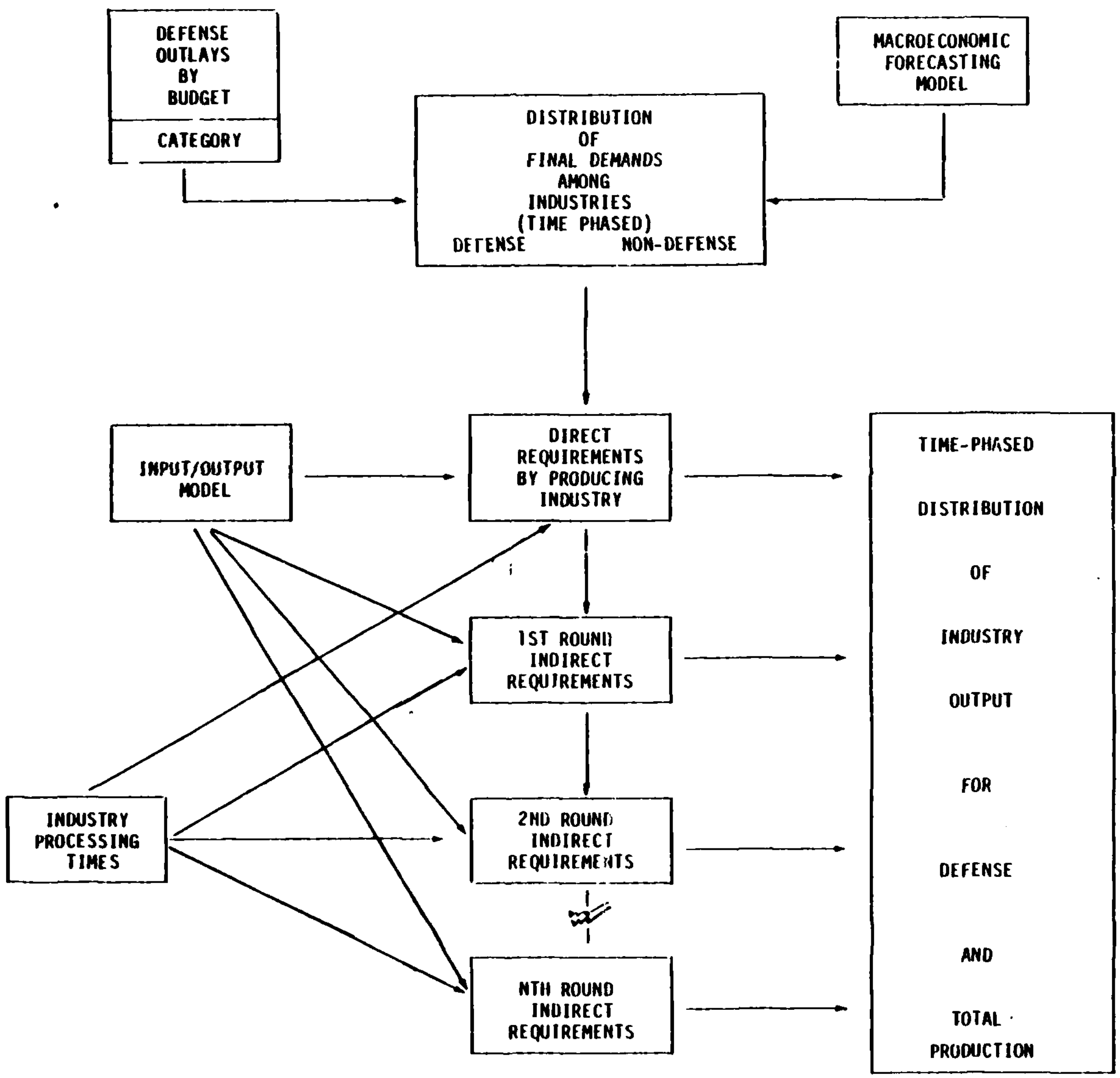

Figure 3. INDUSTRIAL MOBILIZATION POTENTIAL MODEL

Though they share an analytic core--input-output analysis--clearly each of the three models exhibits unique methodological characteristics. For this reason alone, one would expect their forecasts to differ. In addition, the models are distinguishable in a number of other ways. These differences are the subject of the following chapter.

Chapter III

COMPARATIVE ANALYSIS OF THE MODELS

This chapter compares the three models on the basis of several specific characteristics: (1) level of industrial detail, (2) time frame, (3) treatment of capacity and (4) organization considerations. In this way, a potential user can assess the relative strengths and weaknesses of the models according to the criteria which are most relevant to any particular application.

A. LEVEL OF DETAIL

By "level of detail" we mean the number of industry sectors included in the model (and hence, the degree to which those sectors are narrowly or broadly defined with respect to specific products). Our concern here will be limited to manufacturing industrial groups, since the nonmanufacturing areas (mining, construction, trade and services) are not usually considered as potential bottlenecks in a mobilization.[1]

Since all three models begin with the same 496 input/output data categories established by the Bureau of Economic Analysis, all *potentially* could utilize the same level of detail with respect to industrial sectors. However, all three have chosen to aggregate or consolidate industries into larger groups. As a result, DEIMS makes forecasts for 400 industries, IMPMOD for 236, and REGRIP for 115.

[1] This is arguable, especially with respect to mining (critical materials) and transportation. However, the analysis of bottlenecks in these sectors is better addressed through methods other than input-output analysis.

The DEIMS consolidation reflects the decision of the Inter-Industry Service Group at Data Resources Incorporated, and not that of Program Analysis and Evaluation. The reduction from 496 industries to 400 *commodities* was undertaken for three reasons:

- It was necessary to reduce the model's size for computational ease,
- The conversion from industries to commodities left several sectors producing the same commodity,[1]
- Data limitation prevented DRI from updating certain detailed BEA sectors.[2]

For REGRIP and IMPMOD, computational cost and feasibility were the paramount reasons for reducing the level of detail. Because of time phasing, IMPMOD must calculate indirect requirements round by round for every product, and the computer "overhead" associated with keeping track of these production requirements, timing, and ultimately adding them together at every time period, is substantial. The 236-industry pattern adopted in IMPMOD resulted from aggregating industries which are not involved in a major way in defense production to the two-digit SIC level, while retaining all available detail for defense producers and their suppliers.

Table 6 shows the details of the aggregation procedures. The left hand column shows the industrial sectors which were not aggregated. The number in parentheses following each sector shows the number of sub-industries within the sector

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[1]For example, there is a private electric utility sector, a federal government electric utility sector, and a state and local government utility sector in the BEA classification scheme. These all produce the same commodity—electricity.

[2]Data Resources Incorporated, Inter-Industry Service Group, "Technical Documentation," Lexington, Massachusetts, n.d.

Table 6. MANUFACTURING SECTORS IN IMPMOD

BEA Industry Groups Presented in Detail	BEA Industry Groups Consolidated
Ordnance and Ammunition (6)[a]	Food and Kindred Products (44)[b]
Wood Containers (1)	Tobacco Manufacturers (4)
Paperboard Containers and Boxes (1)	Fabrics, Yarn and Threadmills (4)
Chemicals and Chemical Products (10)	Miscellaneous Textile Goods and Floor Coverings (10)
Plastics and Synthetic Materials (4)	Apparel (7)
Paints and Allied Products (1)	Miscellaneous Fabricated Textile Products (8)
Petroleum Refining (3)	Lumber and Wood Products (13)
Rubber and Miscellaneous Products (6)	Household Furniture (6)
Leather Tanning and Refinishing (1)	Other Furniture and Fixtures (7)
Glass and Glass Products (2)	Paper and Allied Products (12)
Stone and Clay Products (15)	Printing and Publishing (15)
Primary Iron and Steel (9)	Drugs, Cleaning and Toilet Products (1)
Primary Nonferrous Metals (14)	Footware and Other Leather Products (8)
Metal Containers (2)	Farm and Garden Machinery (2)
Heating, Plumbing and Fabricated Structural Metal Products (9)	Miscellaneous Machinery, Except Electrical (2)
Screw Machine Products and Stampings (2)	Household Appliances (7)
Other Fabricated Metal Products (11)	Miscellaneous Manufacturing (20)
Engines and Turbines (2)	
Construction and Mining Machinery (3)	
Materials Handling Machinery (4)	
Metalworking Machinery (6)	
Special Industrial Machinery and Equipment (6)	
General Industrial Machinery and Equipment (7)	
Office, Computing, and Accounting Machines (5)	
Service Industry Machines (5)	
Electric Transmission and Distribution Equipment (8)	
Electric Lighting and Wiring (3)	
Radio, Television, and Communication Equipment (4)	
Electronic Components and Accessories (3)	
Miscellaneous Electrical Machinery (5)	
Motor Vehicles and Equipment (4)	
Aircraft and Parts (3)	
Other Transportation Equipment (7)	
Professional, Scientific, and Controlling Instruments and Supplies (6)	
Optical and Photographic Equipment and Supplies (3)	
Total Sectors Retained at Full BEA Detail 181	Total Sectors Aggregated to Two-Digit BEA Level 17 (Representing 170 BEA Sectors)

[a]Number of sectors in group.
[b]Number of sectors consolidated.

which appear as individual entries in the IMPMOD reports.[1] On the right hand side, Table 6 shows the industrial sectors for which aggregation was undertaken. Thus, the 44 industries in the BEA table associated with food products were aggregated to a single IMPMOD industry sector, "Food and Kindred Products."

It is evident from Table 6 that IMPMOD retains all relevant industries involved, directly or indirectly, in defense production. Indeed, the number of industries could be again reduced by (say) one-half if one took the non-relevant sub-industries of those sectors which are presented in detail, and consolidated them. This is the approach which has been followed in REGRIP. Table 7 shows the manufacturing industries included in this REGRIP model. A comparison of the two tables shows that, for instance, Chemicals and Chemical Products are divided into three sectors in REGRIP, versus ten in IMPMOD. As a consequence, REGRIP has only 84 manufacturing industries for which forecasts are generated, versus 198 in IMPMOD.

What are the defense industries which all three model builders elected to present in detail? A careful comparison of the three models reveals 46 industries which are represented at the four-digit SIC code level (the most detailed data available). These are shown in Table 8 and include:

- Aircraft production
- Guided missile production
- Nonferrous metal casting and forging
- Machine tool production
- Communication equipment
- Shipbuilding
- Explosives, ammunition, and ordnance.

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[1]Thus, the Ordnance and Ammunition sector in IMPMOD includes six industries: (1) complete guided missiles, (2) ammunition, except (for) small arms, (3) tanks and tank components, (4) small arms, (5) small arms ammunition, and (6) other ordnance and accessories.

Table 7. MANUFACTURING SECTORS IN REGRIP

BEA Industry Sectors Presented in Detail	BEA Industry Sector Consolidated
Ordnance and Accessories (6)[a]	Food and Tobacco (48)[b]
Chemicals and Chemical Products (3)	Textiles and Apparel (29)
Petroleum Refining (2)	Lumber and Wood Products (14)
Rubber and Miscellaneous Products (2)	Household Furniture (6)
Primary Iron and Steel (5)	Other Furniture and Fixtures (7)
Primary Nonferrous Metals (14)	Paper and Allied Products (13)
Heating, Plumbing, and Fabricated Structural Products (2)	Printing and Publishing (15)
Screw Machine Products and Stampings (2)	Leather and Leather Products (9)
General Industrial Machinery and Equipment (3)	Glass and Stone Products (25)
Electric Transmission and Distribution Equipment (3)	Metal Containers (2)
Radio, Television, and Communication Equipment (3)	Other Fabricated Metal Products (11)
Aircraft, Aircraft Engines, and Parts (3)	Engines and Turbines (2)
Motor Vehicles and Equipment (3)	Farm and Garden Machinery (2)
Other Transportation Equipment (3)	Construction and Mining Machinery and Materials Handling Equipment (7)
Professional, Scientific, and Controlling Instruments (4)	Metalworking Machinery (6)
Optical and Photographic Equipment and Supplies (2)	Special Industrial Machinery (6)
	Miscellaneous Machinery, Excluding Electrical (2)
	Office, Computing, and Accounting Machines (5)
	Service Industry Machines (5)
	Household Appliances (7)
	Electric Lighting and Wiring Equipment (3)
	Electronic Components and Accessories (3)
	Miscellaneous Electrical Machinery (5)
	Miscellaneous Manufacturing (20)
Total Sectors Retained in BEA Detail (60)[a]	Total Sectors Consolidated to Two-Digit BEA Level 24 (Representing 252 BEA Sectors)

[a]Number of sectors in group.

[b]Number of sectors consolidated.

Table 8. FOUR-DIGIT SIC INDUSTRIES INCLUDED IN ALL THREE MODELS

	Industries	SIC Codes
1	Explosives	2892
2	Tires and Inner Tubes	3011
3	Primary Copper	3331
4	Primary Lead	3332
5	Primary Zinc	3333
6	Primary Aluminum	3334
7	Primary Nonferrous Metals, n.e.c.	3339
8	Secondary Nonferrous Metals	3341
9	Copper Rolling and Drawing	3351
10	Aluminum Rolling and Drawing	3353-3355
11	Nonferrous Rolling and Drawing, n.e.c.	3356
12	Nonferrous Wiredrawing and Insulation	3357
13	Aluminum Castings	3361
14	Brass, Bronze, and Copper Castings	3362
15	Nonferrous Forgings	3363
16	Nonferrous Castings, n.e.c.	3369
17	Metal Heat Treating	3398
18	Primary Metals, n.e.c.	3399
19	Metal Containers	3411
20	Metal Stampings	3461
21	Iron and Steel Forgings	3462
22	Nonferrous Forgings	3463
23	Small Arms Ammunition	3482
24	Ammunition, Excluding Small Arms Ammunition	3483
25	Small Arms	3484
26	Other Ordnance and Accessories	3489
27	Machine Tools: Metal Cutting	3541
28	Machine Tools: Metal Forming	3542
29	Special Tools and Dies	3544-3545
30	Pumps and Compressors	3561,3563
31	Ball and Roller Bearings	3562
32	Electrical Measuring Instruments	3611
33	Telephone and Telegraph Apparatus	3661
34	Communication Equipment	3662
35	Motor Vehicles	3711
36	Truck and Bus Bodies	3713,3715
37	Motor Vehicle Parts, etc.	3714
38	Aircraft	3721
39	Aircraft and Missile Engines	3724,3764
40	Aircraft and Missile Parts, n.e.c.	3728,3769
41	Shipbuilding and Repair	3731-3732
42	Complete Guided Missiles	3761
43	Tanks and Tank Components	3795
44	Engineering and Scientific Instruments	3811
45	Electrical Measuring Instruments	3825
46	Photographic Equipment	3861

- Precision instruments
- Photographic equipment.

Thus, all model developers have chosen to present the most relevant defense industries in the fullest detail available. It is in the treatment of more indirect supplier industries that the models differ in coverage.

B. TIME FRAME

Under the heading "time frame" we include two important considerations. The first of these is the basic period of time used in the model's calculations, which we term the "simulation period." The second is the length of time over which the model generates forecasts, which we call the "forecast horizon." These two quantities are related, since if one divides the forecast horizon by the simulation period, the resultant quotient is the number of times the model must be solved to produce a forecast run. This latter quantity is directly related to the computation cost of the model.

1. DEIMS

The DEIMS model uses an annual simulation period and typically generates forecasts for a five year forecast horizon. This corresponds to the Five Year Defense Program. The DRI model is not limited to this forecasting horizon and could be used to generate macroeconomic scenarios for ten to twenty years ahead. Similarly, DEIMS can be exercised for more than five years. However, all of the standard report generator programs are designed to support FYDP analyses and would require minor modifications for the longer period.

2. REGRIP

Computational constraints are most severe for the REGRIP model because it incorporates a dynamic linear programming

model for its solution. Currently, REGRIP uses a semiannual simulation period and forecasts for only four periods (two years) ahead. When a longer forecast horizon is required (as in the recent Attainability Study performed for the JCS), the model must be simulated in two-year increments, with manual input of results from one simulation necessary to restart the simulation process. This is a tedious process, which could be automated if frequency of use justified it. However, the recent installation of REGRIP on the OJCS computer system has eliminated the necessity for this manual adjustment.

3. IMPMOD

In contrast to the above models, IMPMOD used a *weekly* simulation period. Analyses performed with IMPMOD used a ten-year horizon, with five years of preparatory work and up to five years of end-item production. Thus, a total of 520 periods were simulated.

The use of a weekly period originated in the processing time data, which were estimated in weeks. The current version of the model has been revised to perform the calculations using a monthly or quarterly period, as the user chooses. This reduces computation cost considerably.

4. Comments on Time Frame

Only the REGRIP model is significantly restricted with respect to its forecast horizon. Manual procedures used by FEMA to overcome this computational restriction are cumbersome and might require automation if REGRIP were to be selected as the main model for DoD mobilization analyses.

For the other two models, an increase in forecast horizon translates into an increase in computation cost but presents no other major difficulties.

C. TREATMENT OF CAPACITY

The issue of identifying industrial areas where existing capacity limits the potential for industrial mobilization is the central problem addressed by this study. The manner in which the models deal with capacity differs markedly.

1. DEIMS

The current version of DEIMS ignores capacity constraints at the industry level altogether. No data on industry capacity are used in the model and no predictions of capacity output or capacity utilization are generated. The projections of industry demands associated with DoD requirements are estimated without any attempt to assess the feasibility of their attainment.

It is not quite correct to say that the *DEIMS system* (which includes the DRI macro model as well as the DoD bridge tables and inter-industry model) includes no treatment of capacity. The DRI macro model does project capacity and capacity utilization for various industrial sectors, but at a much broader level than the industries of DEIMS.[1]

Data Resources Incorporated has proposed (to the Department of Defense) improvements to the inter-industry model to incorporate forecasts of capacity utilization for manufacturing industries at the input-output level. This proposal appears as Appendix B.

[1]If capacity constraints do exist at the macroeconomic level, they will be reflected in (a) higher prices for manufactured products, (b) higher wages and (c) lower *real* (but higher nominal) consumer demands. However, these effects do not restrict directly the predicted production of DoD output.

2. REGRIP

As benefits a model designed for mobilization analyses, REGRIP deals prominently with capacity and capacity augmentation. Its procedures will be described in detail.

The benchmark estimates of mobilization capacity used in REGRIP were developed based on results of the Survey of Plant Capacity conducted annually by the Bureau of the Census.[1] The Census sample is approximately 8,000 establishments, most of them large manufacturers. The Census questionnaire requests firms to report their actual output as well as their (1) practical capacity and (2) preferred capacity. "Practical capacity" is defined by the Bureau as "the greatest level of output this plant can achieve within the framework of the realistic work pattern."

Practical capacity is further defined by the Bureau to mean the maximum production rate (1) using existing facilities, and (2) assuming no constraints on labor and material supply. In 1974 and 1975, respondents were told in a supplemental instruction[2]

> "If, in estimating capacity for items (1) and (2) [practical and preferred capacity, respectively], you did not assume continuous operations (24 hours a day, seven days per week) as within a realistic work pattern, please mark (X) the extent to which practical capacity could be increased by use of more overtime, shifts, or workdays that you consider realistic."

One-third of respondents said no further increase was possible. One-third reported possible increases of zero

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[1] U.S. Bureau of the Census, Current Industrial Report Series MQ-C1(80)-2, *Survey of Plant Capacity, 1980*, Government Printing Office, Washington, D.C., 1981. Appendix C contains the survey instrument used to collect the data.

[2] *Idem.*, p. A-3.

percent to 20 percent, while the remainder said they could increase production by more than 20 percent.

As a result, the developers of REGRIP chose to increase the practical capacity results. Their procedure was to adjust the reported *industry* capacity figures upward by the percentage necessary to convert the industry to a three-shift per day, seven day a week operation, or if this figure were greater than 40 percent, by 40 percent. Thus, a 1-8-5 (one eight-hour shift per day, 5 days per week operation) would go to 56 hours, while a 2-8-7 operation would be increased to 157 hours. Practical capacity results were then multiplied by this factor to estimate capacity in a national emergency.

a. Predicting Capacity Expansion

The REGRIP model has the ability to add capacity to industries experiencing excess demand, thus simulating the actual pattern of industry capacity expansion. Two data sets were necessary for this:

- Estimates of industry capital-output ratios--to determine the additional investment required, and
- Estimates of investment lead times--to determine the time delay before the additional capacity becomes operational.

The capital-output ratios were determined industry-by-industry by dividing historical data on capital stocks by data on estimated capacity-outputs. Here capacity was determined by adjusting actual output according to the Federal Reserve Board index of capacity utilization. Thus,

$$Q_i^c = Q_i/(U_i/100)$$

where Q_i^c is capacity output in industry i, Q_i is actual output, and U_i is the Federal Reserve Board index value (expressed in a percentage). Then,

$$K_i \equiv K_i/Q_i^c \equiv \frac{K_i \cdot (U_i/100)}{Q_i}$$

yields the industry capital-output ratio (k_i) as the quotient of industry capital-stock (K_i) and Q_i^c .

Note that this procedure uses a measure of capacity output which is closer to the Census "practical" output than the estimated mobilization output. That is, the additional capital is added using a peacetime pattern of capital utilization. This seems inconsistent in a mobilization scenario.

Lead-time data were based on World War II and Korean War experience, for which U.S. government records on plant construction were available. These data are admittedly out of date, but no better estimates are available. The major issue here is the fact that these data were collected before the modern era of regulation impacted on construction times. However, if a national emergency were declared, waivers for construction of essential facilities are authorized by many, but not all, environmental laws.

b. <u>Procedure for Estimating Capacity Expansion</u>

When the projection of direct and indirect requirements for an industry's output exceeds capacity (either practical or mobilization, depending on the scenario), the model will attempt to add capacity to meet the excess demand. The capital expansion itself generates additional demands on other industries;[1] these are added to the assumed final civilian demands. Thus, capacity expansion may temporarily exacerbate the supply situation in critical industries. When the allotted lead time has expired, the additional capacity comes on-line and is used to meet future period demands.

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[1]These are estimated using 1967 BEA data on the industrial requirements of investment projects.

c. An Example

Table 9 is drawn from the 1979 Battelle study.[1] It shows the investments required to meet a wartime mobilization scenario. The scenario proceeds for only two years (four semi-annual forecast periods). Because of the lead time (18 months), only investments in 1979:1 (the first half of 1979) can come on-stream in time to impact production, and then only in 1980:2 (the second half of 1980). The first numerical column of the table shows the additional *initial* (pre-1979) capacity which would have been required to satisfy the demands on the ammunition, aluminum, and steel industries. Because it was unavailable, wartime civilian and military requirements were not fully met and allocation of output was required. The presence of zeros in this column for an industry indicates that the supply constraint only appeared in the final forecast period and was adequately met by investment initiated in 1979:1.

3. IMPMOD

IMPMOD does not *predict* capacity expansion based on requirements; however, it does use the Survey of Plant Capacity data to *compare* industry capacity with requirements. Figure 4 illustrates an output from IMPMOD. Here, capacity is projected to grow at a fixed rate (three percent per year) starting from the 1978 capacity estimate. Total DoD and civilian requirements for each industry's output can be compared to the projected capacity to identify industries with potential bottlenecks.

One problem with the IMPMOD approach is that there is no basis for identifying the correct rate of capacity expansion for each industry. In preliminary analytic runs, the same rate of expansion was specified for all industries.

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[1] "A Model to Identify...," Battelle Memorial Institute, 1979.

Table 9. OPTIMAL MOBILIZATION INVESTMENT BY INDUSTRY

INDUSTRY	ADDL INITL (%) CAPACITY	COST (BIL. 78$)	INVESTMENT STARTED (BIL. 1967$) 1979:1	1979:2	1980:1	1980:2
15 COMPLETE GUIDED MISSILES	.00 (0)	.00	.57	.00	.00	.00
16 TANKS AND TANK COMPONENTS	.03 (3)	.00	.10	.00	.00	.00
17 AMMUNITION, INCL SMALL ARMS	4.93 (185)	1.21	1.99	.00	.00	.00
18 OTHER ORDNANCE AND ACCESSORIES	.00 (0)	.00	.09	.00	.00	.00
29 INDUSTRIAL CHEMICALS	.00 (0)	.00	.30	.00	.00	.00
31 MISC CHEMICAL PRODUCTS	.00 (0)	.00	.41	.00	.00	.00
38 GLASS AND GLASS PRODUCTS	.00 (0)	.00	.11	.00	.00	.00
40 BLAST FURNACES AND STEEL MILLS	5.51 (14)	7.74	2.26	.00	.00	.00
47 PRIMARY ALUMINUM	.96 (29)	1.28	.21	.00	.00	.00
86 COMMUNICATION EQUIPMENT	.00 (0)	.00	1.56	.00	.00	.00
87 ELECTRONIC COMPONENTS, ACCESSO	.00 (0)	.00	.09	.00	.00	.00
92 AIRCRAFT AND PARTS	.00 (0)	.00	1.14	.00	.00	.00
93 SHIPBUILDING AND REPAIRING	.00 (0)	.00	.47	.00	.00	.00
TOTALS		10.23	9.29	.00	.00	.00

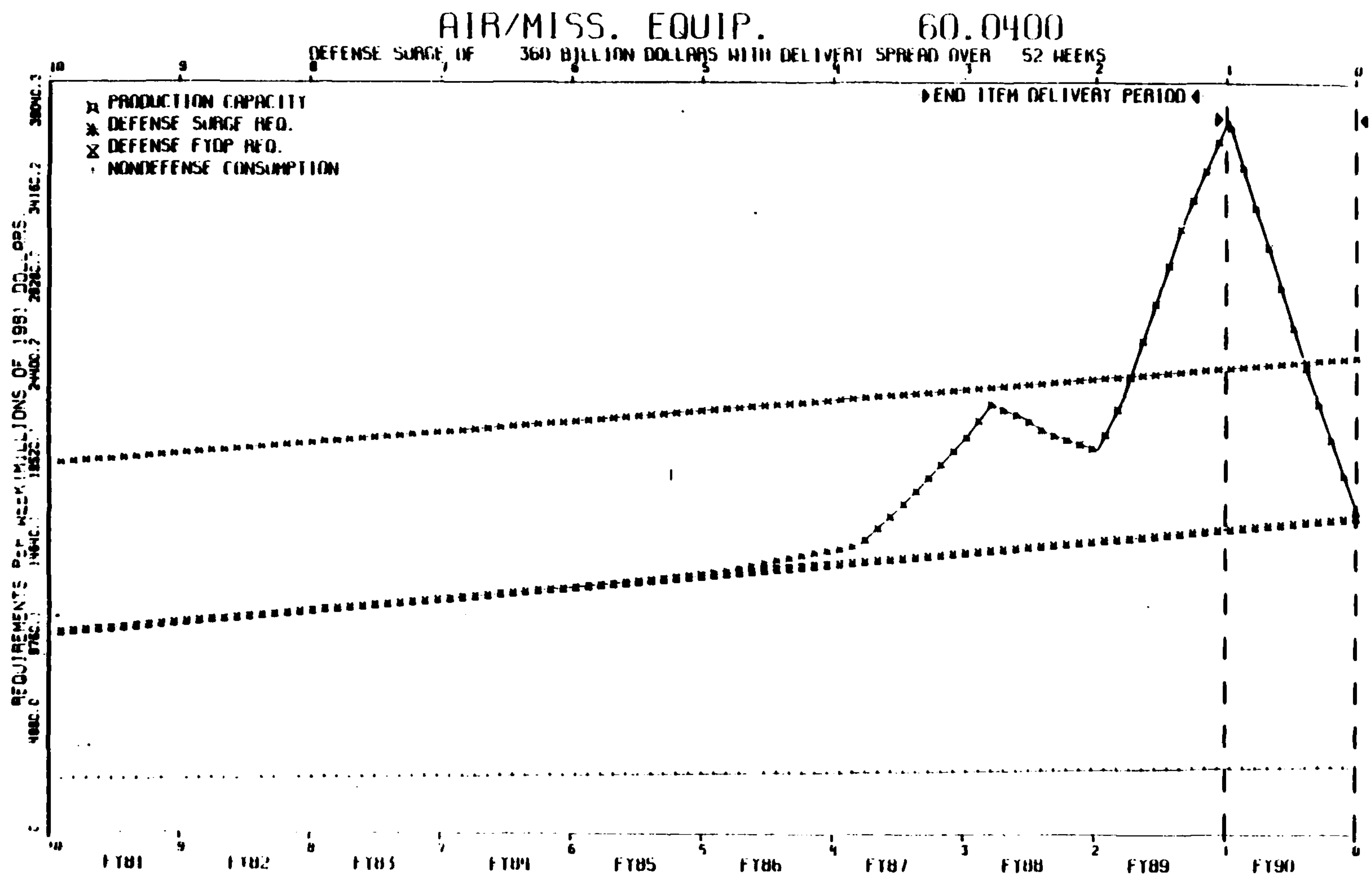

Figure 4. AN ILLUSTRATION OF OUTPUT FROM IMPMOD

D. ORGANIZATIONAL CONSIDERATIONS

Each of the models was developed by or for a different organization. They are characterized by different objectives, different resource bases, and different operating procedures. This section looks at these considerations and how they impact the use of these models by Acquisition Management.

1. DEIMS

The DEIMS system was developed by Dr. David Blond, Cost and Economic Analysis Branch, Program Analysis and Evaluation Directorate, OSD. The primary mission of DEIMS is to assess the industrial requirements resulting from the Five-Year Defense Program (FYDP). DEIMS also has been used to a limited extent for other purposes, including assessing the critical materials requirements associated with surge or mobilization scenarios.

The DEIMS system was implemented by Data Resources Incorporated (DRI) and the software and data physically reside on the DRI computer system. DoD users incur computer processing charges when they exercise the system. Those charges are substantial--$500 to $15,000 dollars per run, depending on the extent of the output specified.

In addition to these charges, OSD has financed the development of the DoD-specific features of the system, including the DoD bridge table and the labor and materials requirements matrices. Through FY 1982, non-recurring developmental costs paid or obligated by DoD total $75,000.

DEIMS may be operated directly by any authorized DRI customer with an active account number (the system is totally unclassified). DRI has implemented a procedure which prompts the user for changes in scenario assumptions, performs the calculations, and outputs the results either directly or to a

remote site printer for transmittal to the user. The user must be familiar with the proprietary DRI operating system EPS to use DEIMS.

2. REGRIP

The REGRIP model effort is directed by Mr. E. Lawrence Salkin of the Federal Emergency Management Agency. REGRIP was designed to identify potential bottleneck industries in a war mobilization. REGRIP has also been used for other analyses. Recently it was used to analyze the feasibility of the Joint Strategic Planning Document Planning Force, in support of a JCS study.

The REGRIP methodology was developed and computer software written by Battelle Pacific Northwest Laboratories under contract to FEMA. Other contractors who support the system include Chase Econometrics, whose model supplies the macroeconomic forecast, and the Interindustry Research Fund, Incorporated (associated with the University of Maryland) who updated the 1972 input-output table to 1977. Total developmental cost for REGRIP is $130,000 through FY 1982.

REGRIP is installed on the FEMA computer system. Funds for the operation of REGRIP are provided through annual allocation; thus, there are no operating costs to users who have the authority to task FEMA to perform a mobilization analysis.

Requests for the use of REGRIP are directed to Mr. Salkin, who prepares the inputs and performs the run; use of REGRIP by others is not encouraged and in fact would be difficult because it is not resident on a commercial system.

3. IMPMOD

The construction of IMPMOD was performed under Task Order T-190 from the Defense Advance Research Projects Agency (DARPA) to the Institute for Defense Analyses. This research was performed in support of the Office of the Deputy Under Secretary

of Defense for Acquisition Management (USDR&E(AM)). The objective of the study was to develop a methodology to incorporate production lead times into input-output analysis and to base predictions of industrial requirements on the time-profile of activities required to eventually produce defense end items.

IMPMOD runs on a CDC Cyber 172 Computer at the Institute for Defense Analyses. Computer costs for a complete model run are approximately $750.

E. OTHER DIFFERENCES

To this point, we have considered only forecasts of industrial output. Both DEIMS and REGRIP also deal with labor and material requirements, but in very different ways.

1. Labor and Material Requirements Forecasts in the DEIMS System

The DEIMS system generates forecasts for employment by industry and by occupation. The DRI employment model generates forecasts of total employment in various industry and service sectors, based on industrial production, wages, prices, and productivity trends. These total employment figures are then distributed to 72 occupational groups, using Bureau of Labor Statistics' actual data and projections for future years. The occupation-by-industry results are then aggregated across industries to develop projections of total occupational demand and the portion of that demand accounted for by DoD production. The occupational groups are shown in Table 10.

Materials requirements associated with the FYDP are established using data on the intensity of material usage per constant dollar of industry shipments. These results are reported for the 63 commodities listed in Table 11.

These forecasts, as well as those for occupations discussed above, are based on an important (and arguable)

Table 10. OCCUPATIONAL GROUPS IN THE DEIMS MODEL

Skill Categories	
ENGINEERS	**SKILLED PRODUCTION WORKERS**
Aero-Astronautic Engineers	Construction Crafts Workers
Chemical Engineers	Blacksmiths and Boilermakers
Civil Engineers	Heat Treaters and Annealers
Electrical Engineers	Forge and Hammer Operators
Mechanical Engineers	Job and Die Setters, Metal
Metallurgical Engineers	Machinists and Apprentices
Engineers, n.e.c.	Millwrights
SCIENTISTS	Molders, Metal and Apprentices
Agricultural Scientists	Pattern and Model Workers
Atmospheric and Space Scientists	Rollers and Finishers, Metal
Biological Scientists	Sheetmetal Workers and Apprentices
Chemists	Tool and Die Makers and Apprentices
Geologists	**MECHANICS AND SKILLED REPAIRMEN**
Marine Scientists	Aircraft Mechanics
Physicists and Astronomers	Automobile Mechanics
Life and Physical Scientists	Data Processing Machine Repair
Mathematicians	Heavy Equipment Mechanics
Statisticians and Actuaries	Machinery and Equipment Mechanics
SCIENTIFIC TECHNICIANS	**GENERAL PRODUCTION WORKERS**
Chemical Technicians	Crafts and Kindred Workers, n.e.c.
Electrical and Electronic Technicians	Drill Press Operators
Industrial Engineering Technicians	Furnace Tenders
Mathematical Technicians	Grinding Machine Operators
Mechanical Engineering Technicians	Heaters, Metal
Other Engineering Technicians	Lathe Milling Machine Operators
Aeronautical Technicians	Metal Platers
Technicians, n.e.c.	Other Precision Machine Operators
Computer Specialists	Punch Stamping Press Operators
MEDICAL WORKERS	Solderers, Welders and Cutters
Physicians and Osteopaths	Printing Trade Crafts Workers
Other Medical Workers Except Technicians	Transportation and Public Utility Workers
Health Technicians	**OPERATIVES AND SERVICE WORKERS**
SOCIAL SCIENTISTS AND OTHER PROFESSIONALS	Other Operatives, Excluding Transport
Social Scientists	Transport Operatives
Teachers, Higher Education	Service Workers
Teachers, Except Higher Education	Construction Workers
Writers, Artists and Entertainers	**LABORERS**
Other Professional and Technical	Other Laborers
BUSINESS PROFESSIONALS AND STAFF	**FARM WORKERS**
Managers, Officials and Proprietors	Farmers and Farm Workers
Stenos, Typists and Secretaries	
Office Machine Operators	
Clerical and Sales Workers	

Table 11. KEY PRIMARY PRODUCTS INCLUDED WITHIN THE DEIMS MODELING SYSTEM STRATEGIC MATERIALS REQUIREMENTS MODEL

ALUMINUM METAL GROUP
- Bauxite
- Alumina
- Aluminum

ALUMINUM OXIDE, CRUDE FUZED

CADMIUM

CHEMICAL AND METALLURGICAL CHROMIUM GROUP
- Chromite, Metallurgical Grade
- Chromite, Chemical Grade
- High Carbon Ferrochromium
- Low Carbon Ferrochromium
- Ferrochromium Silicon
- Chromium Metal and Other

CHROMITE, REFRACTORY GRADE ORES

COBALT

COPPER

DIAMOND GROUP
- Diamond Dies
- Industrial Diamond Crushing Bort
- Industrial Diamond Stones

FLUORSPAR
- Acid Grade
- Acid Grade and Equivalents
- Acid Grade--Hydrofluoric Acid
- Cryolite
- Hydrofluosilic Acid
- Metallurgical Grade
- Sodium Silico Fluoride

GRAPHITE
- Natural--Malagasy Crystalline
- Natural--Ceylon
- Natural--Other than Ceylon and Malagasy

IODINE

JEWEL BEARINGS

LEAD

MANGANESE DIOXITE, BATTERY GRADE GROUP
- Natural
- Synthetic (Electrolytic and Chemical Grade)

MANGANESE METALS GROUP
- Manganese Ore, Chemical Grade
- Metallurgical Manganese Ore
- H.C.F. Manganese and Spiengeleisen
- Medium and Low Carbon Ferromanganese
- Silicomanganese
- Manganese Metal

MERCURY

MICA
- Muscovite Film, First and Second Qualities
- Muscovite Splittings
- Muscovite Block, Stained or Better
- Phlogopite Block
- Phlogopite Splittings

MOLYBDENUM, FERRO AND DISULFIDE

NICKEL

PLATINUM GROUP METALS
- Iridium
- Palladium
- Platinum

PYRETHRUM

QUARTZ CRYSTALS
- Manufactured
- Natural

RUBBER

SILICON CARBIDE, Crude

SILVER

TALC

THORIUM NITRATE

TITANIUM GROUP METALS
- Rutile
- Sponge

TUNGSTEN
- Tungsten Carbide Powder
- Ferrotungsten
- Tungsten Powder

VANADIUM GROUP
- Ferrovanadium and Vanadium Pentoxide

assumption that the amounts of labor and materials used *per dollar of defense production* are the same as the per dollar of *civilian* production. It is possible to identify two sources of bias.

- Given that defense products are more expensive *per pound* than comparable civilian products from the same industry, use of requirements per dollar *overstates* the material requirements of DoD products.
- Given that DoD products use the critical materials *more intensively* than civilian products, per dollar of value, the materials coefficients *understate* DoD requirements.

Since these potential biases are of unknown dimension and operate in opposite ways on the estimates of material requirements, no definitive conclusion on the direction of bias is possible.

2. Labor and Material Constraints in REGRIP

Unlike the DEIMS approach, the REGRIP model uses data on labor and material availability as *constraints* on industrial production. These labor and material constraints complement the restrictions on increasing capacity to define the bounds under which mobilization can proceed.

a. Labor Requirements

From the 425 category BLS occupational-industry matrix, the developers of REGRIP created a consolidated set of 38 occupations (see Table 12). Supply projections for each occupational category are based on (1) the number of workers at the start of the scenario, (2) the assumption that all retirements are postponed for the duration of the scenario, and (3) projection of the number of workers in training (or trainable) within the duration of the scenario. Training and new hire rates are varied from occupation to occupation.

Table 12. OCCUPATIONS USED FOR THE REGRIP STUDY

Occupational Title
1. Aero-Astronautic Engineers
2. General Engineers
3. Other Engineers
4. Scientists and Mathematicians
5. Engineering Technicians
6. Tool Programmers
7. Other Professional, Technicians, Kindred
8. Managers, Officials and Proprietors
9. Sales Workers
10. Clerical Workers
11. Boilermakers
12. Heat Treaters, Annealers
13. Forgemen and Hammermen
14. Job and Die Setters, Metal
15. Machinists and Apprentices
16. Millwrights
17. Molders, Metal and Apprentices
18. Pattern and Model Makers
19. Rollers and Finishers, Metal
20. Sheet Metal Workers and Apprentices
21. Tool Diemakers and Apprentices
22. Aircraft Mechanics
23. Other Mechanics
24. Shipfitters
25. Other Craftsmen, Foremen and Kindred Workers
26. Drill Press Operative
27. Furnacemen, Smeltermen, Pourers
28. Grinding Machine Operatives
29. Lathe, Milling Machine Operatives
30. Metal Platers
31. Other Machine Operatives
32. Punch Stamping Press Operatives
33. Solderers and Welders
34. Riveters and Fasteners
35. Other Operatives
36. Service Workers
37. Other Laborers
38. Farmers

The model user may select some or all occupational groups to include in the scenario under consideration. Omission of any group implies a belief that that labor category will be available in unlimited s pply. In the scenario reported in Battelle (1979), only two occupations--aeronautical engineers and ship fitters--were in short supply. Both these occupations had long training periods (four years under peacetime conditions) which prevented effective diversion of labor from other occupations to meet the needs of the mobilization scenario.

b. Material Supply Constraints

FEMA maintains data on material consumption by industry for 69 critical materials (see Table 11); the user may select subsets of these materials to include in an analysis. Computational restrictions prohibit including all materials in a single run. Material supplies are defined to include (a) private inventories, (b) the Government stockpile, (c) domestic production over the scenario, and (d) imports from secure sources. This supply is available for allocation over the forecast horizon of the scenario.

Material requirements are computed in a manner similar to that used in the DEIMS system. The REGRIP procedure is more general; it includes limited substitutability of more abundant materials for critical ones. This is accomplished by modifying the input-output coefficients and material consumption vectors to reflect the potential for substitution.

In the 1979 Battelle scenario, 18 critical materials were included in the analysis. Supplies of 13 of these 18 materials proved to be inadequate to meet mobilization requirements. The materials in short supply were:[1]

[1] Idem, p. 6.7.

- antimony
- bauxite
- chromite
- cobalt
- copper
- flourspar, acid grade
- flourspar, metal
- lead
- mica
- platinum
- tantalum
- titanium sponge
- zinc

Copper amounted to one-half of the total material shortfall, measured in terms of what it would cost to provide additional inventories sufficient to meet mobilization requirements.

F. SUMMARY OF DIFFERENCES

Table 13 presents an attempt to capture the differences among the three models on a single page. The models differ in their methodology, their industry detail, and their forecast horizon. As is evident, they also differ in terms of the total funds which have been invested in them and their operating procedures.

In the next chapter, we will discuss different sorts of analyses which Acquisition Management might wish to perform, and the capabilities of each model to perform these analyses.

Table 13. SUMMARY OF CHARACTERISTICS OF THE THREE MODELS

Characteristic	DEIMS	REGRIP	IMPMOD
Basis for Macroeconomic Forecast	DRI Macro Model	Chase Macro Model	DRI Macro Model
Methodology to Generate DoD Final Demands	DoD Bridge Table	Same	Same
Methodology to Generate Civilian Final Demands	BEA Bridge Table	"Essential" Demands Specified	BEA Bridge Table
Methodology to Predict Industrial Requirements	Standard Input-Output	Standard Input-Output	Dynamic Input-Output
Methodology to Forecast Capacity Expansion	None	Dynamic Linear Programming Model	Straight Line Extrapolation
Number of Industry Sectors Presented			
All Industries	400	115	236
Manufacturing Industries	318	84	183
Number of Occupational Groups Forecast	72	40	None
Number of Critical Materials Forecast	63	18	None
Forecast Horizon			
Number of Years	5[a]	4[b]	10
Simulation Period	Annual	Semiannual	Monthly[c]
Responsible Organization	Program Analysis and Evaluation (PA&E)	Federal Emergency Management Agency (FEMA)	OUSDRE(AM) Industrial Resources
Operating Agency	Program Analysis and Evaluation, with Support from DRI	Federal Emergency Management Agency	Institute for Defense Analyses
Point of Contact:	Dr. David Blond	Mr. Lawrence Salkin	Dr. R. William Thomas
Total Development Cost	$75,000[d]	$130,000	$75,000

[a] Could be extended with programming changes.

[b] Currently limited to two years by the capacity of the FEMA computer system. The system is being installed on the OJCS computer system without this limitation.

[c] Weekly or quarterly periods are a user option.

[d] Estimated by the author.

Chapter IV

MODEL APPLICATIONS

This chapter considers several distinct sorts of industrial base analyses which Acquisition Management might undertake. After setting out the analytic question and underlying assumptions, it discusses the usefulness and applicability of each model to such an analysis.

A. FIVE YEAR DEFENSE PLAN (FYDP) ANALYSIS

Analytic Question: Are the program requirements of the FYDP feasible to produce? What industrial sectors will experience the greatest strain in meeting these requirements?

Assumptions:

- Peacetime production.
- Civilian and military customers compete for resources on a nearly equal basis; use of Defense Priority System is not aggresively pursued.
- Standard economic outlook for civilian final demand not altered in any way.

This is the scenario for which the DEIMS system was designed. Essentially, it is a peacetime, business-as-usual scenario, and changes in defense requirements are presumed to be incremental in nature.[1] Emphasis in this analysis is placed on (1) identifying the portion of industries' output and employment accounted for by production for defense and

[1]By this we mean that a surge or mobilization scenario which involves sharp increases in production rates is ruled out.

(2) identifying those industries where defense requirements are increasing or decreasing most rapidly, to assist industry in preparing for and accommodating changes in production rates.

For this scenario, DEIMS is the model of choice, although all three models could be used to generate an adequate analysis. The advantage of DEIMS is its detailed treatment of industries whose involvement in defense production is only moderate. Firms in these industries will find that DEIMS' analysis includes their industrial sector, while REGRIP and IMPMOD deal with these firms in terms of larger aggregated categories which are unlikely to be much use to a firm.

The choice of DEIMS stems as well from the fact that its disadvantages are of less concern in this scenario. These disadvantages are (1) its lack of any capacity detail and (2) its lack of information on processing times. In a peacetime scenario, capacity restrictions will be less important and processing times should not change markedly.

If the user is interested only in projections for the 40 (or so) major defense-supplier industries (cf., Table 8, p. 29), any of the three models would be adequate, and their outputs should be similar.

B. JOINT STRATEGIC PLANNING DOCUMENT FORCE ANALYSES

The Joint Staff, in 1982, performed an analysis of the attainability of the Joint Strategic Planning Document (JSPD) Planning Force. The JSPD Planning Force represents a higher level of military force structure in terms of military personnel, equipment, and readiness items (stockpiles of ordnance and other consumables) than the FYPD. Normally, the JSPD Planning Force is not programmed or costed; however, for this analysis, special estimates of the budgetary cost of the 1983-1990 JSPD Planning Force were performed by the Military Departments.

Assumptions:

- Non-defense demands grow according to standard macroeconomic forecast.
- An industrial plant will be built only when projected demand exceeds capacity.
- Manpower and raw materials will be adequate to allow production at the rates projected.
- The force expansion takes place in peacetime.
- Existing domestic and international trade patterns are not disrupted.

The JSPD Planning Force scenario envisions a much higher rate of expansion in defense procurement than even the current FYDP. Unlike the FYDP, it also includes increases in force structure, which would require a significant increase in military manpower with concommitant increases in training facilities, barracks and other military housing, provisions, etc. Thus, the scenario is both deeper (greater hardware procurement rates) and broader (increases in requirements from more industries) than the FYDP.

Given the larger total spending in this scenario, the likelihood that capacity constraints will be binding in the short run increases. In addition, the longer simulation period (1983-1990) means that more emphasis should be placed on capital investment activities that would increase capacity in the out years of the scenario. For these reasons, REGRIP, because of its emphasis on capacity determination, is preferable to DEIMS for this analysis.

It should be recognized that adopting REGRIP means that considerable detail is lost regarding defense production activities of those industries (such as apparel, food processing, and construction) which are not represented in detail in REGRIP. A hybrid procedure which merits consideration is the following:

(1) Formulate the defense requirements associated with producing to meet the requirements of the JSPD Planning Force.

(2) Use REGRIP to identify any capacity restrictions which limit the attainability of this goal.

(3) Revise requirements and stretch out delivery schedules as required to construct a modified program which is attainable, if the original program is unattainable.

(4) Use DEIMS to determine in detail the industrial requirements of this modified program. Aggregate the DEIMS results to the industry sector detail used in REGRIP and compare the results to identify any errors or model inconsistencies.

C. MOBILIZATION SCENARIOS

To this point, we have considered peacetime scenarios. The essential differences associated with analyses of mobilization are noted below:

- In a peacetime scenario, civilian demands are forecast based on projections of personel income, prices of goods, economic outlook, etc., in an unconstrained fashion. In a mobilization scenario, production of certain civilian goods may be curtailed or eliminated to free resources for defense production. Thus, a bill of requirements based only on essential civilian production needs to be specified.
- Mobilization of military personnel may limit the availability of labor.
- Production scheduling would operate on a maximum feasible output basis, rather than on a preferred output basis.
- Budget resources for DoD would be unconstrained.
- Priority in procurement would switch from long-lead-time hardware to the production of sustainability items for deployed weapon systems.
- Increased use would be made of the DPA Priorities and Allocation System to ensure that DoD requirements are met.

- Occupational and environmental regulations might be waived to ensure that the construction of new facilities and conversion of existing facilities are not impeded.
- Certain foreign supplies of materials and products may be disrupted.

In contrast to the FYDP scenario discussed above, possible mobilization scenarios envision major changes in the way DoD interacts with the industrial base. In particular, DoD outputs would command priority over civilian production, and the latter may be restricted to the production of essential civilian goods.

Modeling requirements for this scenario include the ability to:

- Generate an alternate forecast of civilian demand which reflects policy toward continuation of civilian production.
- Simulate the conversion of critical industry production to a maximum feasible output basis.
- Convert certain parts of industry from civilian to defense production.
- Indicate the effects of capital, labor, and material constraints on the attainment of mobilization goals.

Of the models considered here, there is no question that *REGRIP best meets these requirements*. The REGRIP model

- Allows civilian demands to be specified exogenously at lower levels than peacetime.
- Allows the user to select between normal peacetime capacity and mobilization capacity estimates.
- Explicitly models the expansion of capacity, indicating the industries where (a) expansion is required and (b) where capacity constraints limit output.
- Has the ability to specify labor supplies and material inventories as constraints on production. In particular, REGRIP allows

inventories of critical materials to be allocated dynamically over the entire simulation period, not simply on a static period-by-period basis.

The major limitation of REGRIP is its short (two-year) forecasting horizon. Current policy envisions the possibility of a longer period of limited mobilization in a pre-war crisis environment.

In contrast to REGRIP, DEIMS and IMPMOD can only predict the output levels associated with mobilization demands. They cannot use information on labor, material, and capacity constraints to modify forecasts of actual production, nor do they generate predictions of capacity expansion. Of course, the capabilities of these models could be improved. However, at this time, the model of choice for mobilization studies is REGRIP.

D. LEAD-TIMES AND SURGE ANALYSES

On many occasions, specific bottlenecks in the production of critical weapon system components have created lead-times of two to four years before additional units can be delivered. These lead-times were particularly severe in the aerospace industry in 1979-1980, when the following estimates were reported by General Alton D. Slay:[1]

Item	Lead Time (Weeks)
Steel Forgings	82
Titanium Forgings	119
Titanium Plate	92
Aluminum Forgings	81

[1]Statement of General Alton D. Slay, Commander, AFSC, before the Panel on Defense Industrial Base of the Committee on Armed Services, House of Representatives, 96th Congress, 13 November 1980, p. 472.

These lead-times, coupled with normal contracting, fabrication and assembly times, extended the delivery delay for USAF aircraft to 39 to 44 months. They also eliminated any capability to surge or accelerate production rates for these aircraft.

No model considered in this paper can accurately capture the impact of a bottleneck for a specific weapon system part. That sort of impact requires a microeconomic study of the individual systems' production scheduling, using PERT or a similar technique. However, IMPMOD can simulate, at a more aggregated level, the impact of production delays on the delivery of defense products. It does so by estimating a processing time for each input-output industry. These times are then used to model the dynamic pattern by which raw materials are converted to final DoD deliverables.

When estimates of civilian requirements are combined with DoD demands, the analyst, using IMPMOD, can estimate the peak rate of capacity utilization for each industry that supports defense production and also *when*, if at all, production will be constrained by existing or anticipated capacity. Standard models may overestimate capacity utilization in certain periods and underestimate it in others.

The IMPMOD lead-time methodology is a new conceptual development in input-output analysis and is unique to that model. DEIMS and REGRIP, like other models, assume that both direct production of defense items and the indirect production of materials and components for those items occur simultaneously (that is, within the same simulation period--the year, in the case of DEIMS, and a semiannual period, in the case of REGRIP). Clearly, they cannot be used for this sort of analysis.

E. INFLATIONARY IMPACT OF DEFENSE SPENDING

One major issue that arises during any major (peacetime) military buildup is the possible inflationary impact of diverting resources to defense production. This inflationary impact is thought to stem from three sources:

- The general impact of increasing total final demand for goods and services and increasing capacity utilization.
- The concentration of defense requirements on a few key industries (metal forming, critical material resources) and occupations (electrical engineers, machinists, etc.).
- The fact that defense production generates purchasing power but does not augment the supply of goods available for consumer purchase.

The latter argument has been generally discredited by most economists who have addressed it. The first two sources, however, have inflationary potential and deserve a serious examination.

None of the models examined here was designed specifically for inflation analyses. Of them, DEIMS, together with other elements of the DRI macro modeling system, offers the greatest potential for such analyses. The DRI macro model can analyze the inflationary potential associated with increases in DoD final demand. The DRI Cost Forecasting Service can translate these into detailed projections of price increases for specific commodities.

Finally, DEIMS offers the greatest detail with respect to output and employment projections, and thus is most likely to identify specific bottleneck industries or occupational groups.

F. OTHER ANALYSES

It is a truism that the hardest thing for an analyst to forecast is tomorrow's question. Undoubtedly, analyses which differ significantly from those described in this chapter are possible. One characteristic of the models which deserves consideration is the ease with which they may be modified to address different analytic questions, especially those requireing quick answers.

All three models are reasonably complex and therefore not simple to modify. Major additions to their capabilities, such as the prediction of materials requirements by DEIMS or the REGRIP-MIN variant, took six months to a year to implement. As long as changes can be restricted to altering values of model inputs, it should be possible to do a new analysis within a month. However, this restriction means that care should be taken to confine analyses to those for which the basic assumptions of each model's methodology are appropriate.

Chapter V

RECOMMENDATIONS

This chapter addresses issues with respect to the interaction of the Office of the Deputy Under Secretary of Defense for Acquisition Management with the cognizant agencies responsible for the operation of each model. It makes recommendations with respect to (a) tasking of analyses, (b) allocation of USDR&E(AM) research and development funds to model improvements and (c) use of model outputs by Acquisition Management.

In considering these recommendations, it is important to note that Acquisition Management directly controls only IMPMOD. Its position with respect to DEIMS and REGRIP is that of a major user, whose concerns would influence but not necessarily control the activities of the model developer.

Recommendation 1--Acquisition Management should rely on the DEIMS forecast to establish the industrial requirements anticipated on the basis of the current FYDP.

Rationale--Program Analysis and Evaluation has the major responsibility for determining the economic impact of current and anticipated defense spending. The wide public exposure given to DEIMS' output in the defense industrial community suggests strongly the inadvisability of Acquisition Management issuing any contrasting forecast based on a different model or methodology.

__Recommendation 2__--Acquisition Management should annually task FEMA to prepare an industrial mobilization analysis using REGRIP based on the best available plans and estimates for defense requirements based on current mobilization policy.

__Rationale__--REGRIP offers an existing capability to model expansion in industrial capacity, as contrasted to DRI's proposal to do so.

As part of the annual mobilization exercise (in 1982, "PROUD SABRE"), Acquisition Management prepared a statement of defense mobilization requirements and submitted it to FEMA. The latter agency used its modeling capabilities to determine industrial requirements and identify industries where capacity expansion is required. However, these estimates were not well integrated into the exercise and did not impact on the actions of its players. This analysis should be performed well in advance of the command post exercise and the results should be written into the exercise guidance.

__Recommendation 3__--Acquisition Management should provide adequate support to maintain the IMPMOD system in an operational capacity, but should not finance major methodological improvements to this system at this time.

__Rationale__--IMPMOD offers a unique capability for lead-time analyses. However, in some other respects, it is more limited than DEIMS or REGRIP. Lead-times are not a current priority problem, due to the recession in civilian demand. However, the defense buildup, coupled with resurgence of civilian demand in 1984-1985, could cause this problem to resurface. IMPMOD should be tasked annually to identify possible bottleneck industries to which resources could be diverted in time to alleviate the capacity problem.

Recommendation 4--Acquisition Management should support studies designed to provide better estimates of capacity for the most important defense industries.

Rationale--This review has identified a central problem for industrial base planning--the weakness of our data on capacity. There are three identifiable subproblems:

(1) We do not know what the available data measure.

(2) Data are not available at the level of detail we need.

(3) A methodology for forecasting capacity changes needs to be developed and implemented.

The first problem was discussed in Chapter II; there are problems interpreting the results of the Census Survey of Plant Capacity. The available data do not allow us to identify the defense sector of SIC four-digit industries. Finally, historical data are not enough. We need a methodology which can forecast expansion through both (a) new construction and (b) conversion of facilities in a mobilization.

One promising data source which deserves consideration is data collected by the Services for IPP purposes. This is the only source of information on facilities conversion. However, IPP data are relatively narrow in their coverage and must be integrated with the census data.

Recommendation 5--Acquisition Management should concentrate its Research and Development funds on problems associated with the next major business cycle expansion (1984-1986). It should use O&M funds to finance on-going assessment activities.

Rationale--Modeling resources have reached a level of development where they can be integrated into the normal PPBS cycle (as in the requirement that a Production Base Analysis

be included in the 1984 POM). Research and Development funds should be used to look beyond the current recession to the time when the current defense increase crests in 1984-1986.

The specific areas of research which Acquisition Management might want to address (perhaps in conjunction with other Federal agencies) include:

- Studies to improve the measurement of capacity in major defense end-item industries such as shipbuilding, aerospace, electronics, communications, etc. These studies should identify the subsectors of these industries which are equipped to produce defense goods, and the extent to which direct requirements for defense products differ from those for civilian products (i.e., what are the differences in (say) critical materials requirements among fighter aircraft, military transport aircraft, and commercial transport aircraft)?
- Studies to better identify the availability of critical labor skills and the lead time associated with training additional workers for these specialties.
- Studies to identify ways in which lead times may be reduced through the advance purchase and stockpiling of selected materials and subassemblies, or of production or test equipment which are pacing items in the production of military hardware.

Recommendation 6--The Bureau of the Census should be asked to orient their Survey of Plant Capacity more toward determining the physical limit to plant production in a full mobilization. Also, the Survey should identify firms who are defense contractors, subcontractors, or who supply products used in defense production.

Rationale--These changes would make the determination of industry capacity much more precise, and would permit the identification of firms in the defense industrial base. Also, a way should be sought to give DoD access to more specific

data, which it cannot obtain today because of Census' pledge of confidentiality.

Recommendation 7--Acquisition Management should support studies to better identify the material and labor requirements of major defense weapon systems.

Rationale--Preparatory data collection and analysis is required to advance our ability to model increases in defense production in greater detail than present data allow. Service efforts are underway to develop such data; Acquisition Management should support these efforts organizationally and through budget guidance, if required.

Recommendation 8--The Joint Staff should perform an economic analysis of the attainability of the JSPD Planning Force as part of its annual planning cycle.

Rationale--Production requirements necessary to acquire the hardware items and readiness stocks envisioned by the Planning Force would impose strains on a civilian economy, even in a period of moderate economic activity. Although it may be unlikely that the Planning Force would ever be funded in peacetime, an analysis of its implications for the economy would indicate bottleneck areas which could hamper individual weapon systems' procurement in the event of a crisis or a decision to mobilize.

Appendix A

DERIVATION OF INPUT-OUTPUT COEFFICIENTS, AND RELATED TABLES

DERIVATION OF INPUT-OUTPUT COEFFICIENTS, AND RELATED TABLES

This Appendix explains how the input-output coefficients are derived and how they are used to obtain information about the interrelationships which exist in the economy. Basically the input-output techniques provide analyses of interindustry relations and of the network of intermediate goods flowing through the economy, as well as of final products passing to consumers, business, and the government.

The basic data from which the input-output coefficients are derived are obtained from the economic census program which is conducted every five years. From those data, a transaction flow table can be constructed. It shows the magnitude of flows between various industries,[1] i.e., the sales of one industry to every other industry. Table A-1 presents these sales in an abstract form. Purchases of labor inputs and other items such as profits, which contribute to value added, are added to these industrial purchases.

The table is arranged to show the sales of each of the n industries to all other industries (including itself) and to final consumers. The rows represent the output of each industry including final sales; the sum of each row is the value

[1]The Commerce Department makes a distinction between commodities and industries, because a commodity may be produced in more than one industry and the output of each industry is not homogeneous. We shall ignore this real world distinction and assume that commodities and industries are one and the same.

Table A-1. SALES OF INDIVIDUAL INDUSTRIES TO ALL OTHER INDUSTRIES, IN DOLLARS AND PURCHASES OF LABOR

From \ To		Industry 1	2			n	Final Demand	Total
Industry	1	S_{11}	S_{12}			S_{1n}	d_1	
	2	S_{21}	S_{22}			S_{2n}	d_2	$\sum_i S_{ij}$
		S_{i1}	S_{i2}	S_{ii}		S_{in}	d_i	Value of Total Output
	n	S_{n1}	S_{n2}			S_{nn}	d_n	
Labor, etc.		L_1	L_2	L_i		L_n		
Total		$\sum_i S_{ij}$ purchases of inputs from other industries and labor						

of the total output of that industry. The column sums are the value of an industry's purchases from all other industries plus the labor and capital inputs. The variable S_{ij} represents the sales of products by the i^{th} industry to the j^{th} industry.

The coefficients of the input-output matrix, (a_{ij}), are obtained by dividing all the S_{ij}'s in the j^{th} column by the total output of the j^{th} industry. The a_{ij} measures the value of inputs required from the i^{th} industry to produce a dollar's worth of output in the j^{th} industry. These coefficients measure

Table A-2. INPUT-OUTPUT COEFFICIENTS, VALUE OF INPUTS REQUIRED FOR A DOLLAR'S WORTH OF OUTPUT

Industry: From \ To	1	2		n
1	a_{11}	a_{12}		a_{1n}
2	a_{21}	a_{22}		a_{2n}
	a_{n1}	a_{i2}	a_{ii}	a_{in}
n	a_{n1}	a_{n2}		a_{nn}

the direct requirements from the i^{th} industry to produce a dollar's worth of output by the j^{th} industry (Table A-2).

However, these direct requirements do not indicate the total needs for producing a dollar's worth of any final demand. For example, to produce aircraft, steel is required, but in order to make the steel, additional machinery is required, which necessitates more steel. This interaction can be explained by examining the output of each industry. Each sector produces products which are both a final demand and the intermediate inputs for some other industry; i.e.,

$$X = AX + f \,, \tag{1}$$

where X is the vector of output by industry, A is the matrix of input-output coefficients, and f is the vector of final demands by industry. Equation (1) can be manipulated to yield

$$X = (I-A)^{-1} f = Bf \,, \tag{2}$$

where $B = (I-A)^{-1}$ and I is the identity matrix. The coefficients in the B matrix represent the value of the total requirements (both direct and indirect) for the product produced by the i^{th} industry resulting from a dollar's worth of final demand for the j^{th} industry.

The vector f consists of the final demands purchased from each industry, and its derivation requires some explanation. These final demands are estimated from "bridge" tables which allocate fixed amounts of consumption (C), investment (I), and government (G) expenditures to output of specific industries. Thus,

$$f_i = \alpha_i C + \beta_i I + \gamma_i G \tag{3}$$

where f_i is the final demand originating in the i^{th} industry, and the allocation coefficients (α_i, β_i, and γ_i) are determined from census data.

A complication associated with these bridge tables should be noted. In the GNP accounts, consumption, investment and government expenditures are aggregated in terms of purchaser's prices, i.e., the price paid by the final user. On the other hand, in the input-output tables, the values are expressed in producer prices, i.e., the prices received by the producers. The difference between these two prices reflects the value added (gross margin) attributable to the trade and transportation sectors. Thus, in calculating final demands from each industry, a portion of the final purchases are attributed to sales of the trade and transportation sectors. When the magnitude of these services is subtracted from values as measured by purchaser prices, the resulting figure reflects final demand as measured by producer prices. The figures are now comparable.

Thus in using the DoD bridge table which translates expenditures, as measured by 55 budget categories, into final demands from 496 U.S. industries, this subtraction of trade and transportation margins must be made. If this adjustment were not made, the direct and indirect requirements resulting from DoD outlays would be overstated for all industries except the trade and transportation sectors.

Appendix B

AN OPEN PROPOSAL TO DEVELOP AN INDUSTRY CAPACITY MONITORING SYSTEM

Data Resources Incorporated[1]
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[1] Reproduced by permission of Data Resources Incorporated.

AN OPEN PROPOSAL TO DEVELOP AN INDUSTRY CAPACITY MONITORING SYSTEM

The interest in studying and analyzing emerging bottlenecks in industry production has intensified as a result of the OPEC oil experience and periods during the 1970s when shortages of critical materials seemed to be on the horizon. Of more recent interest has been the role of the expanding defense budget and its likely impacts on the production capabilities of important defense-related industries. Given private demands for goods and services, will there be sufficient productive capacity to meet America's growing defense needs without creating significant and unwanted incremental sectoral price pressures? To answer this question three important structural developments are necessary:

(1) An explicit link between demands for a sector's output and its ability to expand capital stock.

(2) A measure of the growth of fully utilized stock by major industrial sector.

(3) A structure which relates sectoral utilization rates of capital to changes in sectoral price.

Data Resources Inc. is in a unique position to develop systems which address the capacity problem directly. Indeed, our vast experience in developing statistical models and using data in numerous and creative ways provides a strong organization foundation for undertaking the challenge of developing micro models of investment behavior. However, the costs (labor, computer, overhead and materials) of developing such a system are, needless to say, quite expensive and although

there is a clear desire on the part of both the private and public sectors for the unique information such a system could provide, the cost may be prohibitive for any one sponsor. As a result, Data Resources is looking for interested parties that will equally share the cost associated with developing the industry capacity monitoring system (ICMS). The following details how such a system will be developed and the kinds of questions that it will be designed to answer.

A. WHO WILL DEVELOP ICMS?

The system will be constructed by the Interindustry Service of Data Resources Incorporated. The Interindustry Service maintains an input-output model which projects constant dollar output for 400 sectors, most of which are the four-digit SIC level. For a given macro scenario, the input-output model provides estimates of output which are required from each sector in order to meet the overall demands of the macroeconomic projection.

B. USING THE INPUT-OUTPUT FRAMEWORK, HOW CAN DEMANDS FOR SECTORAL OUTPUT AND SECTORAL INVESTMENT FLOWS BE RELATED?

In order to solve the input-output model, estimates of final demand components (which include investment in plant and equipment) are necessary. What we propose is to relate changes in sectoral output levels to sectoral investment in plant and equipment and at the same time develop capital stock estimates.

$$I_{it} = f_1 \begin{bmatrix} \sum_{j=1}^{3+} B_j \, O_{it-j} \, , \; \bar{B}_4 \; K_{t-1} \, (1-g_{it-1}) \\ \\ \sum_{j-1}^{3+} \bar{B}_5 \, R_{t-j} \end{bmatrix} \quad I$$

$$K_{it} = I_{it} + (1-R_i)\ K_{it-1}$$

where:

a) I_{it} = investment in plant and equipment (1972 dollars) for sector i, period t.

b) O_{it} = sector i output (1972 dollars) in period t.

c) O^*_{it} = sector i potential output (1972 dollars) in period t.

d) K_{it-1} = sector i capital stock (1972 dollars) in period t-1.

e) g_{it-1} = utilization rate of capital in period t-1 measured as O_{it-1}/O^*_{it-1}.

f) R_{t-j} = economy-wide cost of capital.

g) $1-R_i$ = economic depreciation rate of sector i capital stock is a function of technology, relative resource price changes, etc.

The signs above each of the coefficients indicate the direction of change. The proposed system employs a flexible accelerator specification modified by the actual level of capacity utilization and the cost of financial capital.

The equations will be linked to the input-output model so that when, for example, output of sector i changes, its investment will change, which in turn will cause the output of capital goods supplying sectors to change, which will then influence investment activity by capital goods supplying sectors.

C. HOW WILL ESTIMATES OF FULLY UTILIZED CAPITAL STOCK BE DETERMINED?

For each sector covered, historical points of peak capacity will be identified. This will be accomplished by studying the growth path of sectoral output as well as appealing to historical capacity utilization indices which have been put together by the Federal Reserve Board. To complement this

information, a moving average of the growth rate in sector i's output and price will be constructed. Periods of peak capacity will be isolated by identifying those years for which the growth rate in sector i's output and price significantly exceeds the corresponding moving average growth rate. These peak points will be connected and a potential output growth path will be computed. The ratio of actual output to potential at any time t can be thought of as a rate of utilization of factors of production. When this rate is multiplied by the level of capital stock at a point in time, a measure of utilized capital can be obtained.

D. HOW WILL DEVIATIONS FROM FULLY UTILIZED CAPITAL STOCK BE DETERMINED?

Given the growth rate of sectoral potential output and the latest historical potential output level, projected levels of sectoral potential output can be generated. With this information and a macro scenario, both equation system I and the input model can be solved. The ratio of forecasted sectoral output to projected potential output will again measure the projected utilization rate of sector capacity. These projections can be combined with forecasts of capital stock to produce estimates of the level of capital actually being employed in production. It should be emphasized that this calculation is not merely an exercise in arithmetic but rather is directly related to forecasted investment levels and hence future levels of capital stock. (Note the specification of equation system I.)

E. HOW CAN DETAILED EMPIRICAL WORK IN CAPITAL FORMATION HELP "RED FLAG" POTENTIAL CAPACITY BOTTLENECKS IN KEY INDUSTRIES?

As we have postulated the analytical framework, potential and actual sectoral output are directly related to sector

investment activity and future capital availability. For each industry in the long run, the amount of investment that takes place should be sufficient to sustain long-run potential growth. However, over short periods of time actual output growth could exceed the growth of potential, thus resulting in a sectors utilization rate rising into ranges which have typically been associated with unacceptable increases in output prices. ICMS can provide an early warning system that would identify and track sectors that are coming close to their capacity limitations. This system is particularly relevant to capital goods supplying sectors since current investment demands from non-capital goods sectors must be met through utilization of their existing capital base. If today's investment demands from both the public and private sectors are strong and current levels of utilization are not very low, capacity bottlenecks in these key industries could occur quickly. This is only the beginning, however, since such developments imply possible future capital shortages in the non-capital goods producing sectors of the economy. *ICMS cannot only trace this process but from a public perspective the results can easily give rise to other expenditure paths that would alleviate potential shortages and the market chaos that typically accompany such developments.*

F. AT WHAT LEVEL OF AGGREGATION CAN ICMS BE DONE?

Comprehensive and robust investment and capital stock information (in constant and current 1972 dollars) exists at the two or three-digit SIC level. The aggregation breakdown is also consistent with the 1972 capital flow table recently released by the Bureau of Economic Analysis. For the year 1972, this matrix details purchases of plant and equipment by type for over 70 using industries. Data Resources' Interindustry Service has updated this matrix to 1978 and it is currently incorporated into our input-output model. Hence,

given these linkages, it would seem that development of behavioral investment and capital stock equations at an aggregation level consistent with capital flows would be most appropriate and extremely useful. It is also possible within manufacturing to disaggregate to the four-digit SIC level. Which particular sectors are ultimately modelled will depend on the need of the sponsors of this project.

Appendix C

SURVEY OF PLANT CAPACITY QUESTIONNAIRE

SURVEY OF PLANT CAPACITY QUESTIONNAIRE

DUE DATE: WITHIN 30 DAYS AFTER RECEIPT

Form Approved: O.M.B. No. 41-R2806

FORM MQ-C1
(10-8-80)

U.S. DEPARTMENT OF COMMERCE
BUREAU OF THE CENSUS

NOTICE – Response to this inquiry is required by law (title 13, U.S. Code, sections 131, 182, 224, and 225). By section 9 of the same law, your report to the Census Bureau is confidential. It may be seen only by sworn Census employees and may be used only for statistical purposes. The law also provides that copies retained in your files are immune from legal process.

In correspondence pertaining to this report, refer to the file number above your name.

SURVEY OF
PLANT CAPACITY

FOURTH QUARTER 1980

RETURN TO Bureau of the Census
1201 East Tenth Street
Jeffersonville, Indiana 47132

Please READ carefully the specific instructions with each item on the reverse side before filing this report.

PLEASE RETURN THIS COPY

(Please correct any error in name and address including ZIP code)

GENERAL INSTRUCTIONS

Fourth Quarter 1980 (October–December) – Please complete the information requested for the establishment described in the address box of this form. If your company operates more than one manufacturing location, you are requested to report only for those specifically selected for this survey.

This report will be used to compile estimates of capacity by industry and for manufacturing as a whole in order to evaluate the actual performance of manufacturing in the months ahead. The information is of great value not only to the Bureau of the Census, but also to the Federal Reserve Board, Council of Economic Advisers, and other parts of the Government responsible for tracking the performance of the economy. It is recognized that many companies do not have records readily at hand to compile a precise measure of capacity. It is also recognized that estimated capacity may vary considerably with the product mix which may be subject to substantial short run variation in many establishments. However, past surveys conducted by the Bureau of the Census and discussions with many firms indicate that most firms can overcome these obstacles and estimate the capabilities of the plants reasonably accurately in terms of value of production or another item such as quantity of output or materials put through.

We urge you to make a reasonable effort to complete the various sections of the report form. If you feel that you cannot complete the item 1 data for production or materials, a work-hour estimate of preferred rate and practical capacity is acceptable.

Please use the remarks section to make comments about the method you used to obtain your estimate of capacity. Such comments will enhance the usefulness of the resulting data or will reduce questions we may have about your report.

Shifts Per Day – Most shifts are assumed to be of 8 hours duration so that a 3-shift operation is usually maximum. If you are operating with a variation that leads to more than three shifts or to fractional shifts (such as when departments of the firm operate different number of shifts), please use the remarks to explain briefly your operations.

Days Per Week, Hours Per Day, and Weeks in Operation – Refer to the duration the main portion of the plant is open and operating, not to the work-hours put in by your work force.

Number of Production Workers and Total Work-hours – Should be the same as reported for this establishment on your 1980 Annual Survey of Manufactures Form MA-100 (Items 2 and 4).

Preferred Level of Operations – This is typically an intermediate level of operations between actual operations and practical capacity which you would prefer not to exceed because of costs or other considerations. If no such level exists as far as the plant operation is concerned, please enter "same as practical capacity" in item 1, column c.

CONTINUE ON PAGE 2

GENERAL INSTRUCTIONS – Continued

Practical Capacity – This is the greatest level of output this plant can achieve within the framework of a realistic work pattern. In estimating practical capacity, *please* take into account the following considerations:

1. Assume a normal product mix. If the plant is subject to considerable short run variation in product mix you may assume that the current pattern of production is normal.

2. In setting capacity in terms of the number of shifts and hours of plant operation assume an expansion of operations that can be reasonably attained in your industry and your locality.

3. Consider only the machinery and equipment in place and ready to operate. *Do not consider* facilities which have been inoperative for a long period of time and, therefore, require extensive reconditioning before they can be made operative.

4. Take into account the additional downtime for maintenance, repair, or cleanup which would be required as you move from current operations to full capacity.

5. Assume availability of labor, materials, utilities, etc., sufficient to utilize the machinery and equipment that was in place at the end of the quarter.

6. Do not consider overtime pay, added costs for materials, or other costs to be limiting factors in setting capacity.

7. Although it may be possible to expand plant output by using productive facilities outside of the plant, such as by contracting out subassembly work, do not assume the use of such outside facilities in more than the proportion that has been normal in your current level of operations.

Item 1 – ACTUAL, PREFERRED, AND PRACTICAL LEVELS OF OPERATIONS FOR FOURTH QUARTER 1980 (OCTOBER–DECEMBER) – In reporting shifts, days, and hours of operations you may use the most typical pattern during the period. **Lines 1 through 8** – *Please make every effort to report information requested in columns (b), (c), and (d).*

Line No.	Item (a)	4th Quarter 1980 Actual operations (b)	Preferred level of operations (c)	Practical capacity (d)
1	Shifts per day *(Number)*	1011	1012	1013
2	Days per week in operation *(Number)*	1021	1022	1023
3	Hours per day in operation *(Number)*	1031	1032	1033
4	Weeks in operation during the 4th quarter *(Number)*	1034	1035	1036
5	Number of production workers as of November 12	1041	1042	1043
6	Total work-hours worked during the quarter by production workers *(Thousands)*	1051	1052	1053
7	Percent of overtime hours included in line 6	1061	1062	1063
8	Value of production *($1,000)*	1071	1072	1073

9	*If possible, please report for lines 9 and 10 below. Use reasonable estimates for the item(s) most suitable for your establishments.* Quantity of production – *Specify units*	1081	1082	1083
10	Quantity of materials consumed – *Specify units*	1091	1092	1093

Item 2 – OPERATING RATES DURING THE FOURTH QUARTER 1980

Line No.		Percent
1	At what percentage of practical capacity did this plant actually operate during the fourth quarter 1980?	2011 %
2	At what percentage of practical capacity would you have preferred this plant to operate during the fourth quarter 1980?	2012 %

Item 3 – METHOD USED TO DETERMINE OPERATING RATES – The purpose of this inquiry is to learn how operating rates are computed.

Mark (X) one

2013 ☐ Production workers
2014 ☐ Work hours
2015 ☐ Value of production
2016 ☐ Quantity of production
2017 ☐ Quantity of materials consumed
2018 ☐ Subjective evaluation
2019 ☐ Other – *Specify* ______________

Item 4 – REASONS FOR OPERATING AT LESS THAN 100% OF PRACTICAL CAPACITY AND LENGTH OF TIME REQUIRED TO REACH AND MAINTAIN PRACTICAL CAPACITY – If during the 4th quarter 1980 this establishment operated at less than 100% of your practical capacity, please complete items 4a, 4b, and 4c below.

a. Principal reason your operations fell short of practical capacity. Enter the number 1 through 6 for each applicable item to indicate the *ranking of the reason in importance. Number only those reasons which pertain to your operations.*

3011 ______ Insufficient orders
3012 ______ Inadequate labor force (total or specific skills)
3013 ______ Lack of sufficient fuel or electric energy
3014 ______ Lack of materials or supplies
3015 ______ Strike or other work stoppages, etc.
3016 ______ Other (fire, flood, etc.) – *Specify* ______________

b. Length of time it would require to expand actual operations to practical capacity providing there was sufficient demand for the output –

Mark (X) one

3021 ☐ 1 week or less
3022 ☐ 2 weeks to a month
3023 ☐ 2–3 months
3024 ☐ 4–6 months
3025 ☐ More than 6 months – *Specify* ______________
3026 ☐ Impractical to expand to practical capacity – *Specify estimated percent of practical capacity that could be reached within 6 months* . . . . ______ %

c. Length of time practical level of operation could be sustained (or level specified in 3026 above) . . . . 3031 ☐ *Indefinitely* 3032 ☐ *Only* ______ *months* *(Number)*

Item 5 – Person to contact regarding this report

Name	Title	Telephone – Area code	Telephone – Number	Telephone – Extension

FORM MQ-C1 (10-8-80)